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METROPOLITAN SEWAGE AND WHAT TO DO WITH IT

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METROPOLITAN SEWAGE

AND

WHAT TO DO WITH IT.

A SERIES OF PAPERS RELATING TO THE FORMATION AND EXPENDITURE OF THE METROPOLITAN BOARD OF WORKS. THE SEPARATE SYSTEM OF DRAINAGE AND THE MAIN DRAINAGE SYSTEM. THE NEW STOCK BRICK MAKING PROCESS FOR UTILIZING SEWAGE SLUDGE.

A SCHEME OF

SEWAGE DISPOSAL FOR THE METROPOLIS,

AND

THE AUTHOR'S SCHEME OF DRAINAGE

FOR THE

LOWER THAMES VALLEY

INCLUDING AN ACCOUNT OF THE COMPETITION AND

DETAILED ESTIMATES OF COST.

THE WHOLE BEING A COMPLETE SYSTEM OF

SEWAGE CLARIFICATION AND PURIFICATION.

BY

EDWARD MONSON, Assoc. M. Inst. C.E.

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CONTENTS.

INTRODUCTION.

The Sewage Commission—The Metropolitan Board of Works not pleased with it—The Metropolitan Scheme of Drainage does not include a System of Sewage Treatment—The Plan of Main Drainage seriously departed from—The Board of Works have no Settled Scheme—The Estimate for the Works greatly exceeded—Present Rate of Expenditure not satisfactory—Quite time for Inquiry into the Metropolitan System of Drainage—Metropolis Local Management Act does not permit casting Sewage into the Thames—Sewage Mud, what it is—Formation of Shoals in the River—The Cause of Shoals—The question of Sewage Disposal only a Matter of Cost—The Board of Works having no time to devote to Sewage Disposal, why not hand this matter over to the City Authorities?

CHAPTER I.

EVENTS LEADING TO THE FORMATION OF THE METROPOLITAN BOARD OF WORKS, AND THE ADOPTION OF THE PRESENT SYSTEM OF DRAINAGE, IN CHRONOLOGICAL ORDER.

Early Sewage Commissions—The First Metropolitan Commission—Jurisdiction extended to all places within 12 miles of St. Paul's—Various Schemes of Drainage—Mr. Phillips' Plan—The 116 Competition Plans—Mr. Foster's Plan—Messrs. Bazalgette and Haywood's Plan—Mr. Ward's Plan on the Separate System recommended by the Secretary of State—The Board's Plan not approved by Commissioners of Works—Referees (Messrs. Galton, Simpson and Blackwell) appointed—Suggestions of Referees—The Board of Works appoint Messrs. Bidder, Hawkesley and Bazalgette to report; who disagree with the suggestions of the Referees—The Plan of Main Drainage never legally approved—The Estimates for the Works insufficient—The Original Estimate—Actual Cost of Works.

CHAPTER II.

EXEMPLIFICATION OF THE SEPARATE SYSTEM OF DRAINAGE, AS PROPOSED BY THE GENERAL BOARD OF HEALTH.

What is meant by the term Separate System—The correct Principles of Drainage laid down by General Board of Health—Erroneous views of the Metropolitan Commissioners of Sewers, and their ill effects—The Public Health Act does not extend to London—The Water-closet—The Ash-closet and The Tub Systems—Arguments in favor of the Separate System of Drainage—Surface Water Drainage—Sewage Drainage—Back Drainage—Sewage Gas—Ventilation of Sewers—Results.

CHAPTER III.

THE COMBINED SYSTEM OF DRAINAGE AS ADOPTED BY THE METROPOLITAN BOARD OF WORKS FOR THE DRAINAGE OF THE METROPOLIS.

The term Combined Drainage explained—The reason for adopting the Combined System—The Metropolis North of the Thames—The Eastern District—The Western District—All the Sewage brought to Abbey Mills—The Pumping Stations—Engines and Pumps at Western Station—The Sewers—Ventilators—Side Entrances—The Low Level Sewers are Sewers of Deposit—Formation of Sewer Gas—The mode of Cleansing the Sewers—The Number of Flushers for the Main Sewers; The Westminster District; St. James'; St. George's, Hanover Square—Sanitary Defects.

CHAPTER IV.

IMPERFECTIONS OF THE METROPOLITAN SYSTEM OF DRAINAGE, AND PROPOSED REMEDIES. THE CAUSE OF FLOODING, AND HOW IT MIGHT BE PREVENTED.

The advantage of having High Level and Mid Level Sewers not turned to account—The Drainage of the Western District not satisfactory—The Original Plans included a separate Sewage Works for this District—The Plans seriously departed from—The Western joined to Eastern District—The cause of Flooding—How Flooding might be prevented—Money wasted to construct Storm Relief Sewers—Will throw System out of harmony—The Cost incurred in consequence of the mistake of the Metropolitan Board of Works—The Systems compared—The Separate System recommended—Extension of the Metropolitan System to the Lower Thames Valley.

CHAPTER V.

A PROPOSED METHOD OF SEWAGE DISPOSAL FOR THE METROPOLIS NORTH OF THE THAMES.

The Present Works a failure as regards the disposal of the Sewage—The effect of discharging Sewage into the River—The Nuisance from the Sewage—Shoals are formed—It is desirable to reduce the quantity—UTILIZATION SCHEME—The author would cut off the Western District and make three separate Sewage Districts—PRECIPITATION SCHEME—The Sewage to be Treated with Lime at the Present Works—Depositing Tanks to be constructed on the Marshes—The Sludge to be Utilized in the Manufacture of Bricks.

CHAPTER VI.

THE AUTHOR'S NEW METHOD OF UTILIZING SEWAGE SLUDGE.

Sludge accumulation—Opinions of Commissioners, &c., as to its Value—Drift—Organic Matter—Sludge or Malm—The Cement Process—Invention of the Stock Brick Making Process—Importance of the Invention—Opinions of Eminent Engineers as to the Sludge Difficulty—A Profit from Sewage Sludge—A few Remarks about Brick-making.

PART II.

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CHAPTER I.

CULTIVATION OF THE SOIL, THE DISCOVERY, MANUFACTURE AND USE OF ARTIFICIAL MANURES.

Preparation of the Soil—Three kinds of Vegetable Life—Drainage and cultivation alters the character of the Soil—Plant Food—Three kinds of cultivated Plants—Farm Yard Manure—Town Manure—Artificial Manure—Phosphatic; Nitrogenous; Potash; and Soda Manures—Lime—Gypsum—Carbon.

CHAPTER II.

THE VALUE OF SEWAGE CONSIDERED THEORETICALLY AND COMMERCIALLY.

Erroneous Notions as to the value of Sewage—The Conclusion come to is that it has not a Commercial Value—Sanitary Authorities must pay for Sewage Disposal.

CHAPTER III.

IRRIGATION—SEWAGE FARM.

Irrigation, when and where Practiced—Sewage Irrigation—To Purify Sewage—Sewage Farm—The Situation Important—The Soil must be of a Permeable Character.

CHAPTER IV.

THE AUTHOR'S SCHEME OF DRAINAGE AND SEWAGE DISPOSAL FOR THE LOWER THAMES VALLEY, WITH ESTIMATES OF COST, BEING A COMPLETE SCHEME OF SEWAGE CLARIFICATION AND PURIFICATION.

Difference of opinion as to the best method—The author divides sewage purification into two stages—SCHEME A—The District divided into Northern and Southern Divisions—Site of Works—The Sewers, &c.—SCHEME B—Site of Works—The Sewers, &c.—Clarification of the Sewage—The Lime process—The Sewage Works—Sludge Extractor—Size of Tanks—Fittings to Tanks—Working the Tanks—Sludge—Purification of Sewage by Oxidation—Filtration area—How laid out and worked—The office which Land performs in Purifying Sewage—What is pure Water?—The Theory of Sewage Purification—Substances which are formed by the Decomposition of Sewage—Many mistakes made from not being acquainted with this theory—Various statements as to the quantity of Sewage that may be put upon an Acre of Land—Detailed Estimate of Lower Thames Valley Scheme A—Detailed estimate of Scheme B—Estimate of the annual cost of Works.

INTRODUCTION.

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A ROYAL Commission having been appointed to inquire into, and report upon, the system under which sewage is discharged into the Thames by the Metropolitan Board of Works; whether any evil effects result therefrom, and, in that case, what measures can be applied for remedying or preventing the same. The following observations are respectfully submitted, by the author, who has given very much attention to the drainage of the metropolis and the Thames Valley. He published a pamphlet upon the former subject in 1875, which is incorporated in this work, and was one of the engineers who was honoured with instructions from the Lower Thames Valley Main Sewage Board, to prepare a scheme of drainage for their district. He was employed by the Society of Arts to report upon the Metropolitan Sewers; is the inventor of a process for disposing of the sludge of sewage in the manufacture of bricks, has prepared schemes of drainage for various sanitary authorities, and is therefore well acquainted with the subject under consideration.

Any one who has a knowledge of the present state of the Metropolitan Drainage question will at once admit the necessity for the present inquiry, but it does not seem to meet with the entire approbation of the Metropolitan Board of Works, who appear to be in a state of alarm for fear they should be compelled to dispose of their filth in some more decent and scientific manner than at present.

To cast their sewage into the Thames is their pet method of sewage disposal, and if we judge from the discussion now going on they regard every person who thinks differently, as an enemy to their cause. They object to inquiry, and they object to some of the Commissioners, on the ground that they have a previous knowledge of the subject. But has not every eminent engineer a previous knowledge of this subject? If their system be as perfect as they wish us to believe, they need not fear the result of inquiry, but if it will not bear investigation we can readily understand their reason for objecting. However, as the commissioners are men of the highest standing in their profession, we have every confidence in their judgment and their previous knowledge is one of their chief qualifications.

The main drainage, so far as it has been at present carried out, is not a comprehensive system,

because there is no provision for the disposal of the sewage, and no settled scheme of drainage, and because it does not include all those parishes the sewage from which naturally flows into the Thames within the limits of the Metropolitan District. The plan adopted by the Board of Works has been seriously departed from, and flooding has been the result, and to prevent this, works (not included in the said plan) are now in progress, to the amount of about seven hundred thousand pounds. It is a piecemeal, not a comprehensive system of drainage, The Metropolitan Board of Works have no settled scheme, and they are even now partly changing their system. But what right have they to spend our money in this way? As Ratepayers we are entitled to have a definite scheme and to know the probable cost of the work when it is completed, including a system of sewage disposal. The present way of expending money for drainage and the present rate of expenditure is not at all satisfactory, as much of it might have been avoided; and they have exceeded their estimate for main drainage to the extent of £3,400,000.

Again the Board of Works adopted their scheme of drainage one month previous to the repeal of the Section of the Metropolis Local Management Act, which required their plans to be

approved by Her Majesty's Commissioners of Works and Public Buildings, and it would thus appear that they have expended upwards of five-and-a-half millions of money upon a scheme of drainage, the plans for which were never legally approved!

Surely it is quite time there should be some inquiry into and report upon the system under which sewage is discharged into the Thames by the Metropolitan Board of Works, and in the interests of the ratepayers the proceedings in this matter require to be very narrowly watched.

At the present time experiments are being made with floats. The following extract is from *The Builder* 14th October, 1882:—"At the meeting of the Court of Common Council on the 5th inst., Mr. Stoneham asked whether the chairman of the Port Sanitary Committee could give the Court any information as to the progress made by his committee in the matter of the prevention of the pollution of the river Thames. Also whether the chairman could tell the Court what progress had been made by the floats placed in the river at Crossness and Barking, nearly three weeks ago, and how long, judging by the test, it takes for the sewage to reach the sea. Mr. Davis (chairman of the Port of London Sanitary Committee) replied, that they were taking very active steps in this

inquiry, but it was impossible to give any decided answer to the first question. As to the second question, regarding the floats, there was unfortunately some little delay. The floats were not suitably constructed, and they were replaced in his presence on Sunday. This was a continuous work, and if they had lost one tide the experiment would be worth nothing. The float that had reached the furthest point towards the sea was at Shorley Battery, about two miles below Gravesend. Only three floats reached there within from seventeen to nineteen days. There was only one float up the river towards Richmond, which had got as far as Chelsea. One float, by some extraordinary circumstance which had not yet been explained, had never left Barking, but was still in the neighbourhood of the sewage."

The Metropolitan Board of Works were called into existence as a sanitary authority, they took the place of the Metropolitan Commissioners of Sewers, and the work they were appointed to do, was to abate the nuisance arising from sewage being discharged into the Thames; but in this they have utterly failed. Instead of abating the nuisance they have simply transferred it from one place to another, and whereas it was distributed along the Thames over a large area, they have concentrated the sewage all at one point and intensified the nuisance.

The casting of raw sewage into the Thames is directly contrary to the statute. The Metropolitan Board of Works are elected under the Act of 18 and 19 Vic., c. 120. By section 135 of the said Act, the main sewers, then vested in the Commissioners of Sewers for the City of London, and the Metropolitan Commissioners of Sewers, respectively, were vested in them, and they were required to make "such sewers and works as they may think necessary for preventing all or any part of the sewage within the Metropolis from flowing or passing into the River Thames, in or near the Metropolis, and shall cause such sewers and works to be completed on or before the 31st day of December, 1860." And the latter part of the section says, "and may cause the sewage and refuse from such sewers to be sold or disposed of as they may see fit, but so as not to create a nuisance."

Is it not, therefore, as much the duty of the said Board to dispose of the sewage and refuse from the sewers, as it is to make the sewers? But as the case now stands, the river is polluted to a considerable extent, and the navigation impeded by the sewage mud.

Sewage mud consists of the insoluble elements of sewage; the mud and sand washed from the roads; and the chalk and earthy matter precipitated from the water by the refuse soda in the sewage,

which has been used in washing: this being discharged into the river must necessarily silt it up and form shoals.

There is a very considerable amount of deposit in the sewers, if not, why do the Metropolitan Board of Works constantly employ 130 flushers?

As stated hereafter, the Parish of St. George's Hanover Square, removes 450 cubic yards of drift from their sewers alone in the course of a year, but this is a mere trifle compared to the quantity from the whole of the sewers of the metropolis, which is not and cannot be removed, and it goes into the river, and being deposited forms shoals.

The author himself has seen an open ditch from which many cubic yards of earth had been washed down the sewers in consequence of alterations which had been made by the Board of Works. Contractors have been frequently fined for washing slurry down the sewers. Now, where does this go to if not into the river, and if it goes into the river must it not also form mud banks?

The daily flow of sewage into the Thames from the Metropolitan sewers in dry weather is stated to be 120 million gallons, and it is estimated that each gallon contains 100 grains of solid matter, which is equal to 765 tons of solid matter discharged into the Thames daily, or 279,225 tons per annum.

On the part of the Board of Works it is stated

that the sewage cannot be deposited in the bed of the river, and there is evidence to show that it tends to scour rather than to form deposits; and they attempt to prove this by stating that opposite the sewage works the bed of the river has been washed away to the extent of 411,000 cubic yards, since the works were first opened.

That the casting of 280,000 tons of solid matter into the river, along with the sewage should increase its depth and improve the navigation is a new idea and rather hard to believe. But that there should be a scour at the point of discharge is just what one would expect, as the large streams which used to flow into the Thames above bridge have been diverted from their natural course and now pass through the main sewers, and being poured into the river at a new point with increased velocity must of necessity produce a scour; but this does not improve the navigation as the soil thus removed is deposited elsewhere, and the finer particles may be carried to a distance and deposited in slack water.

From a consideration of these facts we should conclude that mud banks would be formed in the Thames from the present system of discharging the metropolitan sewage into the river, and in the discussion of this subject at the Institution of Civil Engineers, February 7th, 1877, Mr. Shelford

stated that "He had had access to the plans of the Thames Conservancy; enlargements of some of which, from a little above the Barking outfall to a little below the southern outfall at Crossness, were now exhibited. It was evident from these that a large deposit of mud had taken place. One of the cross sections had been taken opposite the Southern outfall; another opposite Barking; and the third in Woolwich Reach, opposite Woolwich Pier. Those sections shewed that a huge bank of gelatinous sewage mud had formed opposite Crossness. Its maximum depth was 11 feet, and when there, a couple of men pushed a pole down into it 7 feet without reaching the bottom. Opposite Barking there did not seem to be any great deposit, but there was a considerable divergence from the straight line, and it was possible that the configuration of the shore might account for the absence of deposit. At Woolwich, nearly two miles above Barking, the whole bottom of the river was covered with mud of a considerable depth. The sectional area of the river might be the same as it always had been; but that did not get rid of the fact that a large quantity of solid matter in suspension in the sewage was not carried down to the sea, but was deposited in the river. It was to be accounted for he thought in this way: the suspended matter in sewage was of a gelatinous

floccullent character, however light it might be, it was deposited he believed at slack periods of the tide outside the works, and owing to its sticky nature, it there combined with the sand, and when the flood tide commenced, the mixture of sand and sewage was forced up the river where it became cemented together. It was well known that the tide, at its flood, acted in a wedge like way, and disturbed the bottom. That might account for the fact that sewage sludge was found in considerable quantities above the outfall, notwithstanding that the sewage was only discharged on the ebb tide. In proof of this disturbance he might state that samples of the water had been taken during the flood tide, and they shewed that whereas it was comparatively clear at the top when viewed through a glass bottle, yet if taken 7 or 8 feet below the surface, it was thick, and full of suspended matter. * * * The solid matter in suspension must be deposited somewhere at the nearest point outside the works where still water could be found."

It was also stated in discussion that the soundings of the Thames Conservancy Board shew that previous to the discharge of the Metropolitan Drainage into the river, there was a deep channel on the south side opposite Crossness and extensive anchorage used by colliers, but the anchorage no longer

exists and the deep navigable channel is filled up with sewage mud so that the soundings are reduced from 22 feet to 10 feet and from 22 feet to 11 feet, and the shoal extends far into the centre of the river, and whereas, fish was formerly kept alive at Barking in well boats, they are now obliged to be kept at the mouth of the river in consequence of the sewage.

The metropolis is quite unique in not having a system of sewage disposal, and is the only place in all England where the sanitary authority is now permitted to discharge untreated sewage into running water, and as there is really nothing to prevent its being clarified except the cost, and that would only amount to about £60,000 or £70,000 per annum, besides the cost of Works; even if the refuse were all shot to waste. Is it not therefore quite time that the disgrace attached to this subject should be removed?

The latest idea is to limit the use of the sewers in the city, and complaint has been made that the slurry from asphalte roads is swept down the gullies. As this is polluted water and sewage in every sense of the word, and as the cheapest, best and most efficient way to remove it from the city is by suspension in water, is not such a proceeding in accordance with the principles of sanitary science, and were not the sewers constructed for this

purpose? Are the ratepayers of the City of London to be deprived of the use of their sewers because the Metropolitan Board of Works have neglected to provide proper works for intercepting the sewage from the Thames, and does not this objecting on their part, shew that the sewage does pollute the Thames?—and they know it.

The Metropolitan Board of Works took the place of the Metropolitan Commissioners of Sewers; were called into existence expressly to remove the sewage from the Thames; for this purpose they maintain an expensive establishment; keep a large staff of engineers; and have almost unlimited powers: but yet, with all these advantages, they have utterly failed to do the work for which they were formed, and the Thames is more polluted now than when they first took office.

The Board undoubtedly consists of very able men, but the fact is they have too much to do, and what with gigantic financial operations—colossal improvements—the administration of the building laws—promoting markets and railways—developing electric lighting and building bridges—they have no time to devote to so common a subject as sewage disposal. Under these circumstances, therefore, would it not be well that this matter should be handed over to the City Authorities, who do every thing so promptly, and what they do, they do so well and efficiently.

SEWAGE TREATMENT AND DISPOSAL OF SLUDGE.

CHAPTER I.

EVENTS LEADING TO THE FORMATION OF THE METROPOLITAN BOARD OF WORKS, AND THE ADOPTION OF THE PRESENT SYSTEM OF DRAINAGE, IN CHRONOLOGICAL ORDER.

Early Sewage Commissions—The First Metropolitan Commission—Jurisdiction extended to all places within 12 miles of St. Paul's—Various Schemes of Drainage—Mr. Phillips' Plan—The 116 Competition Plans—Mr. Foster's Plan—Messrs. Bazalgette and Haywood's Plan—Mr. Ward's Plan on the Separate System recommended by the Secretary of State—The Board's Plan not approved by Commissioners of Works—Referees (Messrs. Galton, Simpson and Blackwell) appointed—Suggestions of Referees—The Board of Works appoint Messrs. Bidder, Hawkesley and Bazalgette to report; who disagree with the suggestions of the Referees—The Plan of Main Drainage never legally approved—The Estimates for the Works insufficient—The Original Estimate—Actual Cost of Works.

FROM the earliest times Commissions of Sewers were issued to the civic authorities, but their jurisdiction at first extended to a distance of only two miles from the city of London; the principal statute was 23 Henry VIII., cap. 5.

On the 17th March, 1807, the

Act, 47 Geo. III., cap. 7, was passed, which extended the jurisdiction of the Commissioners for Westminster, and part of Middlesex, to all the water-courses west of the City of London, extending to, and including, the water-course dividing the parishes of Chelsea and Fulham.

On the 10th July, 1823, a select committee was appointed by the House of Commons to inquire into the laws of sewers.

On the accession of King William IV. in 1830, the Lord Chancellor issued a commission for Westminster and part of Middlesex, and extended the jurisdiction of the Commissioners of Sewers as far up the Thames as Hampton.

In 1834 another select committee of the House of Commons was appointed to inquire into the law of sewers.

From 1843 to 1867 the Lord Chancellor issued seven commissions of sewers.

In December, 1847, the Metropolitan Commissions of Sewers were all united, and this was the first commission whose jurisdiction extended to the whole Metropolis.

In 1848, the 11 and 12 Vic. was passed—"An Act to consolidate and continue in force for two years, and to the end of the next Session of Parliament, the Metropolitan Commission of Sewers," and sec. 1 brings all places within twelve miles of

St. Paul's within the law of sewers. Their jurisdiction was divided into districts or areas draining into the same sewers, and these districts were again divided into "levels," and a different rate was levied in each level.

In 1849, Mr. Phillips, surveyor to the then Commissioners, prepared a plan to drain the metropolis, and in the same year the 12 and 13 Vic. c. 93 was passed—"An Act to amend the Metropolitan Sewers Act," and a second commission was appointed.

In 1850 the Commissioners advertised for plans for draining the metropolis, and 116 schemes were sent in, but nothing was done.

In 1851 a third commission was appointed, and a committee examined the competition plans, and reported against them all. In the same year, Mr. Foster, the engineer of the Commissioners, prepared a plan for the main drainage of the metropolis, which was adopted by the Commissioners, and contracts were taken for part of the works, but they were not executed for want of funds.

In 1851 Mr. Foster died, and in the same year Messrs. Stephenson and Cubitt were appointed consulting engineers.

In 1852 a fourth commission was appointed, and a fifth commission later in the same year.

In 1853 the Great London Drainage Bill was

promoted, and the evidence was ordered to be printed on the 17th June.

On the 24th May, 1853, Mr., now Sir J. W. Bazalgette, the engineer to the Metropolitan Commissioners of Sewers, and Mr. Wm. Haywood, the engineer to the City Commission of Sewers, were associated for the purpose of re-modelling the scheme of the late Mr. Foster for the main drainage of London, so as to accord with the views of the consulting engineers of the Commission, and they presented their report 21st January, 1854; the consulting engineers, Messrs. Stephenson and Cubitt, having previously approved of their plans. This scheme for the drainage of the districts north of the Thames was made to embrace an area of fifty-nine square miles, instead of confining it to the forty square miles proposed by Mr. Foster's plan, it was divided into four districts, northern, middle level, and low level areas, and western division.

1853 and 1854 was an important epoch in the drainage of the metropolis. Cholera was raging at that time, and it was in 1854 that the Commissioners adjourned *sine die* on receiving a letter from the Secretary of State recommending the *separate system of drainage* for the Metropolis, according to a plan prepared by Mr. Ward, and in the same year the Commissioners, having voted the sum of one hundred thousand pounds for drainage, were

recommended by the Secretary of State to suspend all main drainage works for the present; and it appears that at this time everything connected with the main drainage was in a very troubled and disturbed state.

In 1855 a sixth commission was appointed, partly by the Government and partly by election, and on 14th August, 1855, The Metropolis Local Management Act, 18 and 19 Vic., cap. 120 was passed, which came into operation on 1st January, 1856, and sec. 136 required the Metropolitan Board of Works to submit a plan and estimate of the proposed main drainage to the Commissioners of Her Majesty's Works and Public Buildings, and accordingly we see by the Referee's report, ordered to be printed by the House of Commons, 3rd August, 1857, that on the 3rd June, 1856, a plan was submitted to the said Commissioners, and rejected on account of the outfall being contrary to the statute.

On the 5th November, 1856, another plan was submitted to them, and that also was rejected on account of the outfall being so near to the metropolis. Referees were then appointed, and the plans of the Metropolitan Board of Works were submitted to the Referees, Messrs. Galton, Simpson, and Blackwell, for their report, and they reported on 31st July, 1857.

At page 212 of the said report is Mr. Bazalgette's plan for main drainage, adopted by the Metropolitan Board of Works after the passing of the Metropolis Local Management Act, and it is very much like the plan of Mr. Foster; the Metropolitan Boundary is shown as defined by the Act, but the sewers are omitted, as if it were not considered desirable to show too much; the outfall is shown at Rainham, and an alternative line to sea reach. At page 6 the Referees report as follows:—"But we must express our decided opinion that if the River Thames is to be effectually relieved from the sewage which flows into it within the limits of the metropolitan district, it is essential that the scheme of drainage to be adopted should embrace not only the metropolitan districts, but all those outlying districts the drainage from which is included in the same area by the natural features of the ground." And again, at page 11—"The plan upon which the Metropolitan Board of Works propose to drain the London district is briefly as follows:—On the north side of the Thames it is proposed to divide the district into three distinct drainage areas, viz:—high level area, middle level area, the low level and western districts, which include the remainder of the Northern metropolitan area, as well as the portion of the upper valley of the Thames, which is not now included in the metropolitan area, but which is

described by Mr. J. W. Bazalgette, engineer to the Metropolitan Board of Works, as 'prospective area.' The drainage of the Western district is divided into two portions, of which one, consisting of about one-third, is collected in the Counters Creek sewer, and flows into the low level sewer." On Page 12, under the heading, Amount of Sewage provided for, it says:—"The quantity of sewage to be removed for which the plan of the Metropolitan Board of Works provides has been computed by Mr. Bazalgette as follows:—The upper portion of that part of the main valley of the Thames in which the metropolis is situated has been added to the metropolitan districts as 'prospective areas,' and the whole have been divided into sections, of which some have been considered to be urban, and some to be suburban. It has then been estimated that the population of the urban districts will rise to 30,000 per square mile, if they have not already attained that amount; and the suburban districts will attain to a population of 20,000 per square mile."

After the report of the Referees there was a correspondence, and in a letter of the Metropolitan Board of Works, dated October, 1857, they say "That they have no legal power to adopt those recommendations of the Referees, which are directed to the object of intercepting the sewage of extensive districts situate beyond the limits of the metropolis as defined by law."

The Referees say in reply,—"The only districts which we have included besides those termed 'prospective area' in the plan of the Metropolitan Board of Works, are districts, the sewage from which naturally flow into the Thames within the limits of the metropolitan districts. We have already stated at length in our report the arguments in favour of including the drainage of an enlarged area in that of the metropolis. Further consideration of this question strengthens our conviction upon this subject."

The Metropolitan Board of Works appear to have been displeased with the report of the Referees, and on the 23rd November, 1857, appointed Messrs. Bidder, Hawkesley, and Bazalgette to consider the report of the Board on the intercepting of the drainage of the metropolis submitted to the Commissioners of Her Majesty's Works and Public Buildings, and also the report of Messrs. Galton, Simpson, and Blackwell upon the same subject, with instructions to report to the Board as to the best means of carrying out the main drainage of the metropolis.

On the 6th April, 1858, Messrs. Bidder, Hawkesley, and Bazalgette made a very severe report in reply to the Referees, and recommended a plan of drainage which did not carry out the recommendations of the Referees. The Metropo-

litan Board of Works adopted this plan 29th June, 1858, and it was not approved by the Commissioners of Her Majesty's Works and Public Buildings, as required by the Act of 1855. The Act of 21 and 22 Vic., cap. 104, repealing the enactments requiring the approbation of the Commissioners of Her Majesty's Works and Public Buildings, was not passed until 2nd August, 1858. The Metropolitan Board of Works have therefore carried out their scheme of main drainage for the metropolis, and expended upwards of 5 millions of money upon a plan which has never been legally approved.

The estimate of the Metropolitan Board of Works was insufficient, and this was brought to their notice by the Referees, who were appointed to consider the scheme of drainage proposed to be adopted. At page 30 the Referees say: — "In respect to the estimates of the works, we are of opinion that in order to carry into effect a plan which involves many difficult engineering works, and which interferes with many public and private interests, a much larger amount of expenditure will be required than that which has been provided for in Mr. Bazalgette's estimates."

The estimate for main drainage when the Act of Parliament was obtained was only £2,300,000, and that included a separate sewage works for the western district, a considerable length of main

The correct principles of town drainage were laid down by the General Board of Health many years since, but they were controverted by the Metropolitan Commissioners of Sewers, who, to a great extent, neutralized the good done by the General Board of Health; and the sewage difficulty, as it is called, has been in a great measure owing to the erroneous views of the said Commissioners, whose example has been followed by other towns. The General Board of Health advocated the separate system, and the removal of excreta by suspension in water. The Metropolitan Commissioners of Sewers, on the other hand, advocated the combined system: the former recommended the use of small glazed earthenware pipes for sewers, the latter recommended large brick sewers; the one recommended that the sewer be laid at the back of the houses, so as to avoid the presence of sewage gas within dwellings; the other laid their sewers under the streets in front of the houses, and beneath each house they carried a long drain from back to front. Up to the present time we have made no advance on the principles of drainage, laid down by the General Board of Health.

As a matter of health, it is desirable that all excretal matter should be at once removed from the neighbourhood of dwellings, and it was proved to demonstration by the General Board of Health,

some years since, that the cheapest, best, and most efficient method of doing this is by suspension in water, but then, on the other hand, the adoption of the water-closet system involves the necessity of clarifying the sewage before turning it into a natural stream or water-course.

The Public Health Act, of 1875, extends to all England—except the metropolis! Why should the metropolis be excepted? Section 17 is as follows: "Nothing in this Act shall authorize any local authority to make or use any sewer, drain, or outfall for the purpose of conveying sewage or filthy water into any natural stream or water-course, or into any canal, pond, or lake, until such sewage or filthy water is freed from all excrementions, or other foul or noxious matter, such as would affect or deteriorate the purity and quality of the water in such stream or water-course, or in such canal, pond, or lake."

Where there is a sufficient water supply the water-closet system is unquestionably far in advance of any other method that has yet been introduced; it is cleanliness itself, independent of the scavenger, and within the control of the household; it is simple, neat, and efficient; the mere pulling of a handle or the turning of a tap being all that is required for effecting the object; it is so great a boon to the country and so great a gain to public

health, that, notwithstanding the apparent loss of manure, the system is never likely to be given up by towns where it has been adopted.

Many new systems have been introduced, but the water-closet is superior to them all; the dry-earth system requires manual and team labour to supply the earth, which renders the product of less value and increases the cost of removal; the ash-closet is simply an ash-pit and privy combined; the tub system is disgusting if not injurious to health, and whilst the water-closet is almost self-acting, these systems require manual labour to replace the receptacles and remove their contents, which is attended with cost; the storage in yards and the removal in carts through the streets are a nuisance; the unnecessary intrusion of strangers into every premises is unpleasant, inconvenient, and indelicate, and during the small hours of the night creates a feeling of insecurity.

There is a very important difference between the sewering of a town and the drainage of a farm, for sewage is water polluted, and contains matter which is so noxious and offensive that covered sewers are necessary for its conveyance, whilst water from land drainage, on the contrary, is clear and fit for use, and being beneficial, wholesome, and pleasant, it is desirable that it should be kept above ground; but this difference is not always kept in view.

As we have seen, it is now compulsory for all towns to purify their sewage before it is turned into rivers and streams. And since the cost of purification will depend upon the quantity of the sewage, it is of the utmost importance that it should be kept in the smallest possible compass consistent with efficiency, and that all land drainage, springs, &c., should be excluded from the sewers. This is called the separate system of drainage, and it is specially applicable to villages, country towns, and to large towns situate on the side of a hill, with open spaces and agricultural land beyond.

Some persons run away with the idea that this system is very costly, but this is a great mistake. There are others who think that efficiency can only be secured by large and costly works, and this also is an error, for in a properly devised scheme the works are not necessarily large or expensive.

The following modification of the separate system of drainage was designed and carried out by the author in 1863 and 1864, at Halstead, in the county of Essex, and is given here as a fair illustration of the system recommended by the General Board of Health.

The plan of the works is that of "pipe drainage on the separate system, and back drainage," the sewers being coterminous with the water supply, sluice valves being placed at the ends of the water

mains, and the whole of the system of sewers being flushed by the discharge of water for cleansing the water mains, or from a large pond at the extremity of the system.

Not aiming at entire separation, the rainfall, streams, and surface water were kept entirely free from sewage, and discharged into the Mill-head: the house drainage or sewage was conveyed in pipe drains to a point beyond the town, to be afterwards dealt with. As the rainfall upon houses and yards is beneficial for flushing, one drain was considered sufficient for each house, and the rainfall in that case was not kept separate from the sewage; but care was taken to exclude from these sewers, as far as possible, all water that was not required for cleansing or for conveying the solids. *The separation, in this case, consisted in keeping the surface water and streams quite free from sewage;* and this is a practical exemplification of the separate system as set forth in this paper. The author considers that the mistake hitherto made has been the attempt to keep sewage free from rainfall—a thing which is impossible. Let us be content if we can keep rainfall free from sewage.

Clean water is almost as important to us as the air we breathe: it is necessary for our domestic wants and to support life; it is required for municipal purposes and to water our roads; it feeds our

streams, rivers, and lakes; it drives our mills, and is essential to our trades and manufactures; it supports fish life, adds beauty to the landscape, and adorns our parks. The consumption of water is daily increasing, whilst, in consequence of the covering in of streams, and the practice of turning clean water into sewers, and sewage which has not been purified into rivers and streams, the supply fit for use is daily decreasing. And again, the supply of water is not now so large as it formerly was, because the rainfall is removed from the land much more quickly than it used to be, and the land being better drained the springs are reduced in quantity. Besides this, the deep-seated springs have been in some cases polluted by dead wells and absorbing wells The storage of water not being sufficiently attended to, is one of the causes of our deficient supply, and another cause is the adoption of the combined system of drainage. If the separate system were universally adopted, and the water which is now wasted recklessly, and inconsiderately, were preserved, there would in some places be abundance as of old, where now we hear constantly increasing complaints of scarcity. It is very poor management to bring water from a distance at the cost of many thousand pounds, when we might have an ample supply at home if it were properly stored and kept free from pollution.

Water is common property, which belongs to and ought to be enjoyed by all, it is, therefore, not only unreasonable and thoughtless to cover in streams and pollute rivers, but we have no right to do so; one community ought not to pollute that which belongs to another community residing lower down the stream. Clean water does no good in sewers, and it is not wanted there except for conveying solids and for flushing the sewers.

Pipe Sewers possess the following advantages: they are self-cleansing and free from deposit; they are comparatively free from sewage gas, and as the sewage gas, if formed, can be readily flushed out, they are conducive to health; they are comparatively free from vermin, for in them rats have no convenience for lodgment; they can be examined at the manholes equally well with brick sewers, and cleaned out with rods, if required; but they require a sufficient supply of water; and flannels, scrubbing-brushes, &c., should be kept out.

Brick Sewers, on the other hand, unless there is a considerable flow of water, are apt to fill up; they then act as gas generators and gas holders, from which the gas cannot be conveniently expelled; for this reason they have been called elongated cesspools and sewers of deposit: they harbour rats. But brick sewers can be examined by means of side entrances and manholes, and men can pass along

them and remove any deposit or obstructions without breaking up the streets. This is certainly an advantage, but obstructions ought not to happen, and in a properly constructed system of drainage rarely do happen.

Halstead is situate upon two hills, which are separated by the river Colne. It is an agricultural town, but there is a crape manufactory, which employs upwards of 1500 hands. A small quantity of velvet is woven in the town, and a great number of women and children are employed in straw-plaiting. The river is headed up, and drives part of the machinery in Messrs. Courtauld's crape factory, and a flour-mill higher up. Previously to the system of drainage being carried out, the sewage was discharged into the Mill-head in the centre of the town, the watercourses were polluted to a considerable extent, and there was a nuisance from the want of drainage at almost every house.

Surface-water Drainage.

The surface-water drainage included street drainage in most cases, land drainage, storm water, and springs. The watercourses were allowed to flow above ground in their natural channels; because sewage being cut off, it was not necessary to cover them over excepting through the town. They were passed under the streets in separate sewers. The existing sewers being cleaned out, repaired, and

reconstructed when necessary, were for the most part used for this purpose

Back Drainage and Sewage Drains.

Almost entirely new lines of pipe sewer were laid at the backs of the houses for sewer drains, of sufficient capacity to receive the sewage only, which included the rainfall from houses and yards.

The sizes of the pipes were respectively 6, 9, and 12 inches, and a short length of 15 inches. The main sewer was a half-brick barrel, and only two feet in diameter. The sizes of the sewers were calculated according to the squares of the diameters, so that by no possibility could the sewers in the lower part of the town be blown or called upon to do more work than they were capable of. Many of the streets were drained with only 6-inch pipes, and that size was found sufficient.

The system of back drainage combines the greatest degree of efficiency with the greatest degree of economy; and if a pipe should chance to leak, it is into the open air, so that it keeps sewage gas outside the house. Drains under houses ought to be laid with iron pipes, or water tight joints, and ventilated outside the house, as most of the foul smells in houses arise from badly jointed drains being laid beneath the floors, and from the want of ventilation.

Back drainage answers most admirably when it

is placed under the care of the sanitary authority especially if the water supply is under the same direction. But it is of the first importance to the proper working of a system of pipe sewers and back drainage that it be regularly inspected and flushed when required; if applied to a few private house it does not answer at all, for it being no person's duty to keep the main drain open it gets stopped, and notwithstanding that it is a great nuisance, one neighbour will not always allow another to enter upon his premises to unstop it. Besides this, it is not fair to throw upon one person, living at the end house it may be, the expense and trouble of keeping open a sewer which is for the common benefit.

The sewage drains at Halstead were so designed that sewage from the upper part of the town could be applied to the adjacent land by gravitation. The drains were coterminous with the water supply, and laid at an average depth of only five feet. It was at first intended to lay them at a depth of ten feet, but on taking the sections it was found that five feet would be sufficient to drain the lowest floor of every house in the town but one.—The least rate of inclination was 1 in 273.

Great attention was paid to flushing. The main sewer in Head Street, and the greater part of the system was flushed by the pond before mentioned. The lower portion could be flushed from the Mill-head

if required. The branch sewers were flushed by the water mains, which communicated with the sewers in the following manner. Sluice valves were placed at the ends of the mains, and when the sluice valves were raised to cleanse the mains it flushed the sewers. In the neighbourhood of London this water would be discharged upon the surface of the street, washing it away. In other cases it was arranged to flush the sewer, from the hydrants, with the fire-engine hose, and private drains could also be cleansed by the same means.

Manholes and inspection shafts were provided at various places along the lines of sewer and at the junctions of sewers, and the rule was that all house drains should be trapped, but the gullies communicating with the surface-water sewers were not to be trapped.

Sewage Gas and the Ventilation of Sewers.

The author believes the recognised principle to be that the sewer authority shall ventilate the sewers, and the owners ventilate the house drains.

In this system the sewage, from its entry into the sewers to its discharge, continued to flow on so that it had no time to decompose and liberate noxious gases, and the formation of sewage gas was prevented to a considerable extent by keeping the sewers free from deposit, by keeping down the

temperature of the sewers by flushing, and by ventilation.

The sewers were ventilated by means of rain-water pipes, properly jointed, and carried up to the roofs of the houses at places where the gases would not be discharged into the bed-rooms. A few charcoal ventilators were put in, and were useful at the ends of the sewers to mark their terminations. But all kinds of charcoal ventilators with which the author is acquainted are imperfect and troublesome, and he considers that the charcoal obstructs the passage of the gas, and hinders ventilation. To make sure, some persons use a mixture of animal and vegetable charcoal. It is now considered best to have openings in the middle of the street, and allow the sewer gas to escape without obstruction. In some cases the gas is allowed to escape after passing through charcoal placed in the side of the gullies.

The compensation paid to the occupiers was only at the rate of 9*d.* per rod. There was no opposition on the part of the owners to the back drainage, for being less costly, they found it was to their advantage. And there were only two or three claims for owner's compensation. The population of the district was 8,000. The total length of new sewers was 5,900 yards. The total cost only £1,500.

The execution of these works entirely cleansed the Mill-head from sewage, and restored all streams and water-courses to their original state of purity. The water, which would otherwise have been contaminated with sewage, was preserved fit for domestic or manufacturing purposes, and being conveyed to the Mill-head was utilized to supply the river and drive the mill. In estimating the results of this system, the value of the water thus preserved must be taken into account, as also the increased value of the sewage. The back drainage was very cheap and most efficient. A short length of pipe, which had a quick fall, and was not likely to be stopped, sufficed for a connection, and the drains were kept outside the houses, which at the present time is the most approved form of drainage. There was no necessity for long and costly lengths of drain pipes under the floors, which mostly have a slow fall, and are not unfrequently badly laid, and imperfectly jointed, and there was no risk of poisonous gases escaping within the dwellings. The houses being free from sewage gas were, consequently, more healthy and comfortable homes for the working population. The yards were most efficiently cleansed. The pipes, being truly laid and connected with the water mains, were self-cleansing, and on being examined twelve months after the completion of the works they were found to be perfectly free from

sediment or deposit of any kind. The rainfall from the houses and yards, whilst it did not perceptibly increase the cost of main sewers, was beneficial for flushing the house drains, and the owners were saved the cost and the inhabitants the annoyance of laying a second set of private drains on every premises, letting alone the difficulty of obtaining entire separation. The sewage was reduced in bulk, and was, therefore, more constant in quantity, more convenient for treatment, and, in its concentrated form, more valuable for irrigation. The cost of constructing large and expensive brick sewers and manure tanks was saved.

CHAPTER III.

THE COMBINED SYSTEM OF DRAINAGE AS ADOPTED BY THE METROPOLITAN BOARD OF WORKS FOR THE DRAINAGE OF THE METROPOLIS.

The term Combined Drainage explained—The reason for adopting the Combined System—The Metropolis North of the Thames—The Eastern District—The Western District—All the Sewage brought to Abbey Mills—The Pumping Stations—Engines and Pumps at Western Station—The Sewers—Ventilators—Side Entrances—The Low Level Sewers are Sewers of Deposit—Formation of Sewer Gas—The mode of Cleansing the Sewers—The Number of Flushers for the Main Sewers; The Westminster District; St. James'; St. George's, Hanover Square—Sanitary Defects.

HE term combined system of drainage, is used here to convey the idea of having one set of sewers for all purposes, constructed to receive not only the sewage but the land drainage and storm-water as well. The term is used as the opposite of the separate system, just described; and it is not meant to convey the idea of combining several towns together for the purpose of drainage, as, for instance, the towns situate in the Lower Thames Valley.

This system appears to have been adopted upon the theory that rain falling upon the streets is as much polluted as sewage, and ought to be treated as such, and this, perhaps, is correct as to a few

main streets, but these are the exception and not the rule, for there are thousands of streets in London in which there is but little traffic and to which this theory does not at all apply.

The whole of the metropolis is drained by this system, but the author in this volume intends to deal only with that part of it which is North of the Thames, and consists of two distinct drainage areas, which, for convenience of reference, we shall call the Eastern and Western districts.

The Eastern district extends from Bow on the East, to Notting Hill and Shoot-up Hill on the West, and is drained by three large main sewers, which pretty nearly follow the contour of the ground, and are called "The North High-Level Sewer," which, running through Hackney, Stoke Newington and Holloway, terminates at Kentish Town. "The Middle-Level Sewer," which, diverging from this at Victoria Park, is carried along Bethnal Green Road, Old Street Road, Oxford Street, to Notting Hill, where it turns off and terminates at Kensal Green. "The Low-Level Sewer" commences at Abbey Mills pumping-station, and is carried across to Limehouse Basin, along Back Road, Royal Mint Street, Lower Thames Street, Cannon Street, to Blackfriars Bridge, along the Thames Embankment to Whitehall, along Victoria Street and Belgrave Place to the Western pumping-station.

The Western district extends from Notting Hill to Shoot-up Hill on the East, to beyond Stamford Brook on the West. It is drained by the Counters Creek Sewer, which pretty nearly follows the line of the creek to the Royal Crescent, from whence there is a branch to Acton. The main line sewer, Western division, commences at the Western pumping-station, and is carried across to Walham Green, along Fulham Common Fields to Hammersmith, and passing under the creek, is continued to Chiswick. Out of this there are branches along the Stamford Brooks.

At present the whole of the sewage from both the Eastern and Western districts is brought to a point at Abbey Mills, and the low-level sewage is lifted to a height of 36 feet into the outfall-sewer, so as to be on the same level as the sewage of the high and mid-level sewers. From this point an embankment has been constructed to near Barking Creek, a distance of four miles, and in this is laid three separate large outfall sewers.

The sewage of the Western district is brought to the Western pumping-station along a sewer 5 feet in diameter, which has a fall of 4 feet to the mile, the invert at the pumping-station being 19 feet below Ordnance Datum. It is lifted 18 feet and discharged into the low-level sewer, along which it flows to Abbey Mills, and is then again lifted 36 feet,

together with the low-level sewage, into the out-fall sewer, and goes on to the works near Barking Creek, where it is discharged into the Thames at the ebb-tide. During the flow of the tide the sewage is stored in a large reservoir, and during a storm the sewage can be, and is, discharged direct into the Thames within the metropolis by means of connections with the river, called storm overflows, and it can be pumped into the river.

There are two pumping-stations, the one at Abbey Mills, which is a very handsome building, in the form of a cross, with a good deal of stone-carving externally, and the interior beautifully decorated; the highly-finished and well-kept steam-engines, eight in number, working sixteen pumps, are placed at right angles to each other, two being placed in each bay of the building; the steam-boilers and the whole of the mechanical arrangements are of the highest order. There is a large sewage tank under the floor of the engine-house, from which the sewage is pumped, and gratings or cages are placed across the low-level sewer to intercept anything that would injure the pumps.

The other, the Western pumping-station, is situate in the Grosvenor Road near Chelsea Bridge, adjoining the railway, and was opened on the 5th August, 1875. There are four steam-engines of 85 nominal horse-power, working eight pumps, 5 feet $3\frac{1}{2}$ inches

diameter, and 4 feet stroke. Besides this, in case of a break down, there is an auxiliary engine of 120 horse-power, working two double-action 4 feet pumps and having a 4 feet stroke.

The sewers for the most part are constructed of brick, but some are made of concrete. They are ventilated by means of gratings placed in the centre of the streets, and there are side entrances which are placed under the paths.

The low-level sewers, constructed at a level sufficiently low to pass under the existing outfall sewers, have no available outlet except by pumping. In point of fact they are not sewers at all, but sewage tanks or reservoirs, and hold the sewage supply for pumping. They are the sludge chambers of the metropolis, and receive the filth of the adjoining parishes. They are elongated cesspools, and unquestionably sewers of deposit. Not being in duplicate they are never entirely emptied. The sewage, therefore, becomes putrid and offensive, and the smell is the subject of frequent complaint.

From inquiries as to the extent of the existence of sewers and drains of deposit in the metropolis made by the author for the Society of Arts, and which extended over a period of twelve months, he found that many of the sewers are not self-cleansing, and in proof of this he noticed the fact that a great number of men are required by

the Board of Works and the various vestries to keep the sewers open and in working order. Dr. Liddle, Medical Officer of Health, says, in answer to the questions from the Society of Arts, "That the sewer belonging to the Metropolitan Board is almost always very offensive at the south end of Dock Street and Nightingale Lane, by the London Docks entrance. Some of the main sewers contain a large quantity of deposit, which compels a frequent cleansing of them and the deposit is taken out of the sewer and removed by the aid of carts."

In some cases the old flat-bottomed sewers, originally constructed for surface water, have been utilized for conveyance of sewage, and these as a rule are not self-cleansing, but sewers of deposit, a natural consequence of the sewage being spread over a wide surface and retarded by friction. A flusher says that in some cases the sewer bottom is not regular, and the filth accumulates in the pot-holes to the depth of a foot or eighteen inches, and there have been frequent complaints in the papers.

Some of the smaller sewers belonging to the vestries are not self-cleansing, and being inconvenient to work in and difficult to inspect, they get neglected. In a case of this kind the informant says that when he inspected the sewer it contained upwards of a foot of filth in a state of putrefaction; and without doubt

there are many other places in a similar condition, but it is very difficult to get reliable information. The author has it on good authority that in a certain district at the West End there are sewers of deposit in a very bad state, but the vestry employ no flushers, and the filth is allowed to accumulate from day to day.

Sewers of deposit mean the decomposition of putrid matter, and the constant formation of sewage gas which escapes through the ventilators in the streets, and through any untrapped openings. In consequence of the traps being left off, through the carelessness of servants, it is discharged into dwelling houses, and finds its way into bedrooms through the open joints of the rain water pipes. Again, during a storm, the low level sewers are filled and the sewage heads up. As the sewage rises, the sewage gas becomes more and more concentrated, and if sufficient means of ventilation are not provided, it is forced up the drains and discharged into dwelling houses through the traps.

The Mode of Cleansing the Sewers.

The sewers not being self-cleansing, it is necessary to employ manual labour to keep them open and in working order. So great is the deposit, that for the main sewers alone, 130 men are constantly kept by the Metropolitan Board at this

work, and the sewers for this purpose are divided into six sections, three on either side of the river. The men are called flushers, and are paid 4s. 6d. a day. They are divided into gangs of about five men. To every gang there is a foreman, and to every twenty men there is an inspector. The open sewers are cleaned out about once a year, the other sewers in rotation, and as required. They are flushed by means of a dam board, which fits the sewer, and has a hole in the shape of a V cut in the lower edge. The dam board being fixed, the sewage heads up, and rushing through the aperture stirs up the deposit, and separates the drift from the organic matter which is flushed on, and at length discharged into the Thames. The drift and other inorganic matter is conveyed in barrows to the man-holes, brought to the surface and used in road making, or sold to "jerry builders" for about sixpence a load. My informant says, that "Vestries are not obliged to construct catch-pits, and slosh is frequently forced down the gullies, and into the main sewers to the extent of two or three hundred loads of deposit at a time." As a rule no deodorants are used. Sometimes there is inflammable gas in the sewers, and on more than one occasion, it has been fired by the light which the men carry on their heads when at work, and they have been injured. At

Wandsworth, two flushers were suffocated whilst working in the sewer, owing to a discharge from some chemical works; two gangs of men had previously refused to work in the sewer.

Whilst the main sewers were being constructed by the Metropolitan Board of Works, the various Vestries and District Boards have spent large sums in the construction of self-cleansing sewers of the egg-shaped pattern; they also employ flushers to cleanse the old flat-bottomed sewers.

In the Westminster district five flushers are employed by the District Board, and they work by day; they are expected to keep the sewers clean, and are not paid for overtime. The wages are £1 5s. per week, and two pairs of boots per year. Deodorants are used in special cases. My informant says that "the deposit comes chiefly from the macadam roads. The sewers are mostly egg-shaped, the inverts of the flat-bottomed sewers having been taken out, and the sewers altered by underpinning. The gullies are trapped, and the sewers ventilated in the middle of the roads. The pipe-sewers are kept clean by occasional flushing, and may be called self-cleansing. The sewage never heads up now, and the main drainage is a decided advantage to this district."

In the St. James's district there are about two miles of main line sewers in Oxford Street, Regent

Street, and Piccadilly, and there is a local sewer over the main line sewer. Three flushers are employed by this Vestry; the foreman has 30s. per week, and the others £1; the hours are from six to half-past five o'clock, and, if additional flushing is required, it is done by contract. Many of the sewers in this district are 5 feet 6 inches by 3 feet, the Westminster pattern. Upon the inverts of some of these, a pipe was formerly laid for the conveyance of sewage, but it became silted up, and the surveyor has had all the pipes taken out and the sewers reinstated. The fat and other stuff coming from the clubs consolidates in the sewers, and is a great deal of trouble. There are fourteen miles of sewer, but it is the three miles in the neighbourhood of Piccadilly upon which the men are principally employed, and their work is greatly facilitated by the rats, and by the vagabonds who go down into the sewers to see what they can find. This district is said to be much improved by the main drainage. A table, showing the various sewers, hangs in the surveyor's office.

In the district of St. George's, Hanover Square, the number of flushers employed is six. The wages of the foreman are 25s., and the wages of the men 24s. per week; the hours are from seven to four o'clock. The men work during the day, and it is estimated that they bring to the surface 450 cubic yards of deposit in a year, which is removed at 4s. per cubic

yard; it consists chiefly of drift and macadam. The flushers are not troubled with fat in the sewers. The population reside only during the season. There are about 52 miles of sewer, and, as a rule, they have a good fall, but in Belgravia the fall is bad. The ventilators are in the middle of the streets and the gullies are trapped. The old sewers are of the Westminster pattern, the new ones egg-shaped. The inverts of the old sewers have been taken out and replaced by inverts of the egg-shaped pattern. There are very few pipe sewers in the district.

Sanitary Defects.

The works are defective in not being self-cleansing. It must be a wrong system which requires so much labour to keep the sewers open and in working order, and which depends very much for its efficiency upon manual labour. In the intervals between the visits of the flusher, the sewers must be left to themselves, and a deposit must be constantly forming, and the organic matter constantly decomposing and liberating noxious gases which pollute the air. The flushing may be well done and well looked after, but still, with sewers which are not self-acting, these things must happen. If a system of self-cleansing sewers had been constructed (and all main sewers ought to be self-

cleansing), so many flushers would not be required, the sewage would not have time to decompose, and the formation of sewer gases would, to a considerable extent, be prevented. The washing of the sand out of the sewage by the flushers is a novel and brilliant idea, but this might be accomplished at much less cost. The drift, which finds its way into the sewer, ought to be excluded, and after it has entered the sewer, it might be intercepted by properly constructed catch-pits. The flat-bottomed sewers might be altered so as to be self-cleansing, and inequalities in the sewers might be removed by reconstruction or lining. The decomposition of the sewage might, to a considerable extent, be prevented by a proper deodorant skilfully applied.

CHAPTER IV.

IMPERFECTIONS OF THE METROPOLITAN SYSTEM OF DRAINAGE, AND PROPOSED REMEDIES. THE CAUSE OF FLOODING, AND HOW IT MIGHT BE PREVENTED.

The advantage of having High Level and Mid Level Sewers not turned to account—The Drainage of the Western District not satisfactory—The Original Plans included a separate Sewage Works for this District—The Plans seriously departed from—The Western joined to Eastern District—The cause of Flooding—How Flooding might be prevented—Money wasted to construct Storm Relief Sewers—Will throw System out of harmony—The Cost incurred in consequence of the mistake of the Metropolitan Board of Works—The Systems compared—The Separate System recommended—Extension of the Metropolitan System to the Lower Thames Valley.

HE system for the Eastern district is extremely good in detail, but it is not a comprehensive scheme of drainage and sewage disposal. The idea of having high and mid-level sewers to take such sewage as can be dealt with by gravitation, and a low-level sewer for sewage that requires pumping, is very clever; nothing could be better; but after being cleverly planned for collecting the sewage, the principle being one of distribution, the advantages of this plan for sewage disposal are entirely thrown away by concentrating all of it at one point and at one level at Abbey Mills. The advantage of collecting sewage at a

high level is not turned to account, and there is a want of harmony between the principles of collection and disposal, the former being one of distribution, whilst the latter is one of concentration.

The Western district is not drained in a satisfactory manner. A large portion of it being agricultural land or open ground like Wormwood Scrubbs and Old Oak Common, was admirably adapted for the separate system, but in this case, also, the combined sytem of drainage has been adopted. The streams have been covered over and treated as natural sewers, and the whole of the sewage from this immense area, plus the water from the large streams, including the rainfall and storm water, of the district, are discharged into the low level sewer of the Eastern district, at Grosvenor Road, by pumping.

The Western district requires particular notice as not being connected with the rest of the metropolis for drainage purposes; it was, at first, very properly treated as a separate drainage district, and the original plans adopted by the Metropolitan Board of Works included a sewage works at Sandy End, Fulham, but a serious departure has been made from this scheme. The Western has been tacked on to the Eastern district, and the sewage, which would have been disposed of at Sandy End, is pumped into the low level sewer of the Eastern

district. But what right have streams and storm-water to be admitted into the low level sewers and twice pumped?

The joining together of the Eastern and Western districts is, without doubt, a great blunder, and cannot now be easily rectified. It causes flooding, is very inconvenient in working, and the sewers are not proportioned to the work they have to do. If the Western district had paid for its own works only, it might have been as efficiently drained and considerably less taxed. The Eastern district pays the Metropolitan Board of Works most handsomely for discharging its untreated sewage into the Thames.

If the water were saved, which is now wastefully turned into the sewers, it might perhaps, with suitable arrangements, be utilized for street watering, flushing sewers, &c. It would not then be necessary to abstract water from the Thames for that purpose, and the ratepayers would save the payments which are now made to water companies on that account. The works at Abbey Mills would be more efficient, and the power of the pumps and engines would not be overtaxed. Instead of the present overflows, tumbling bays and weirs, which are all wonderfully clever in their way, the surface-water would flow away in a pure state through the existing channels, and the pumps in dry weather would have comparatively little to do.

Because the sewage in the low level sewers has all to be pumped, it is very necessary that it should be reduced to the least possible quantity, by excluding all streams, rainfall, storm-water, and all the sewage that will flow away by gravitation; and it is desirable that no more sewage should be brought to the pumps than what they are able to lift; but as we have seen this has not been attended to, and the consequence is that a whole district is liable to be flooded by night or by day, "causing great destruction of property, pecuniary loss, and danger to the public health."

The Cause of Flooding.

The flooding from the low level sewer is from two causes—the one in consequence of the storm-water being collected with the sewage, and the other in consequence of the sewage from the Western district, which is not naturally connected for drainage purposes, being improperly tacked on to the Eastern district, so that the storm-water from a large district containing much agricultural land and open spaces, is received into the low level sewer.

The metropolitan sewers are of enormous size, but notwithstanding that they are unnecessarily large for the conveyance of sewage proper, they are totally inadequate to carry off storm-water,

and during a storm, sewage is discharged into the Thames, within the metropolis from the pumping-station and from the various inlets into the Thames, called storm overflows. They are only made sufficiently large to carry off a quarter of an inch in depth of rainfall in 24 hours, but during a thunder-storm the rain falls at the rate of two or three inches per hour, and at times steadily two inches in 24 hours, and then the houses of whole districts are flooded with sewage, and this is just what one would expect from such an arrangement.

The following extract is from the *Builder* of the 8th May, 1874:—

At the meeting of the Court of Common Council, Mr. Deputy Hora asked whether the Metropolitan Board of Works were taking any, and if any, what steps to prevent the serious inundations after rain-storms, causing great destruction of property, pecuniary loss, and danger to the public health. Mr. Deputy Lowman Taylor, in reply, read a letter from Sir Joseph W. Bazalgette, in which he said, "This Board has diminished the extent and frequency of floodings by carrying off through the intercepting sewers rainfall to the amount of a quarter of an inch in depth spread over London in twenty-four hours. But on the 11th instant the rainfall in the East End of London amounted to an inch and a half in one hour, or 150 more times than our intercepting sewers

and pumps could take. Such storms can only be carried off by what are termed 'the storm-overflows,' which discharge by gravity into the river. These must be above the level of low water, and many of the basements connected with them are so deep that when the sewers are full the water flows back into them. This is the great cause of flooding."

How Flooding might be Prevented.

Flooding in the low level sewer, the author conceives, may now be prevented by cutting off the connection between the Eastern and Western districts, which would so reduce the quantity of sewage that the pumps would be able to lift the remainder, and by cutting off all storm-water, which would not be difficult so far as the low level sewer is concerned, or by lowering the lift of 40 feet and using syphon pumps, so that the sewage should not be lifted to a greater height than the actual difference of level between the water in the sewer and the water in the Thames, and by constructing a low level gravitation sewer at the lowest possible level, so as not only to prevent flooding from storm-water, but to save a great deal of unnecessary pumping.

Flooding might have been prevented if the principle of keeping the streams free from sewage and allowing the clean water to flow into the Thames along the natural channels had been

adopted, as the ancient water ways were sufficient for that purpose except in a few instances, until they were stopped up or altered by the Metropolitan Board of Works. This modification of the separate system of drainage, would have saved us—the ratepayers—a considerable amount of money in the first cost of constructing the works. Besides this the Metropolitan Board of Works are now actually expending £700,000 in the construction of what they call storm relief sewers, the greater part of this expense being obliged to be incurred in consequence of disregarding the advice of the General Board of Health, and adopting a wrong system of drainage. The constructing of these storm relief sewers, will throw the system of drainage out of harmony, and the sewers will not now be of a size proportioned to the work they will have to do.

The metropolis is a very big place and the system of main drainage a very big thing—quite American in its way; with big pumps and engines, and a big lot of sewage, which when discharged into the Thames, is a big nuisance. The idea of concentrating all the sewage at one point is a big blunder; and the flooding of the low-lying district during a storm is a big blot which might have been avoided.

The Metropolitan Board of Works have made a great mistake in adopting the combined system

of drainage as they are now unable to deal with the sewage on account of its enormous bulk, without incurring a great deal of unnecessary expense.

The works for a combined system of drainage are very expensive, there are the costs of sewers and tanks, which must be of enormous size to take in the storm-water, and, if pumping be resorted to, there is the cost of steam-engines and pumps, which must be proportionately large to do the extra work. Then there are the annual cost of pumping, and the extra outlay for chemicals, chemical treatment, filtration and utilization, or some of them. In short, combined drainage means: payment for unnecessary engine power, unnecessary storage room, unnecessary cost for sewers, unnecessary cost for works, and unnecessary cost for labour. But when all this is done, and, notwithstanding all the extra cost and trouble, the works are not so efficient as those of the separate system, which is better in every respect. The works are cheaper to construct, only a small pipe sewer being required for the one, where a large brick sewer is demanded for the other, and it is more economical in working. The sewage in the separate system being concentrated, is comparatively small in quantity, and can be conveniently treated or utilized at small expense, whilst in the combined system it is so much diluted and so large in quantity as to be costly, troublesome,

and difficult to utilize, to treat, or to purify. In the separate system the water is saved from pollution, and, flowing by gravitation, not only feeds our rivers and streams, but increases our water supply, which is running short. In the combined system the water is unnecessarily wasted, and our rivers and streams are starved. In the one case, the water being of great value, is saved and can be utilized for various purposes, besides being "a thing of beauty" and "a joy for ever"; in the other, being polluted, it is lost to the community, and the sewage, greatly increased in bulk, is disgusting and a nuisance.

Such is a summary of the combined system of drainage. Can a system like this last? Impossible! The idea is absurd. Very extraordinary things may happen, but the British taxpayer will never consent to pay large sums of money annually for pumping and purifying water that ought never to have been polluted, and which ought to be at once conveyed to the river by gravitation.

Taking the country through, hundreds of thousands of pounds have been spent in the first cost of works for the combined system of drainage; but, notwithstanding this—looking at the cost and difficulty of treating and disposing of enormous volumes of sewage which has no commercial value; looking at the pollution of streams and also at the scarcity of water, and at all the facts of the case—

the author concludes that—as in the "Railway Battle of the Gauges," notwithstanding the original outlay, and notwithstanding the cost of the alteration, the broad has been altered to the narrow gauge—so, in the matter of sewage, sanitary authorities, who have got a combined system, will be compelled to keep the rainfall free from sewage, and that, subject to various modifications, the separate system of drainage will be universally adopted. And the author predicts that even London, which has spent its thousands upon the combined system, and is spending thousands to maintain it, will even yet be compelled to modify its works and adopt the separate system.

If this were done, the capacity of the sewers for removing excrementitious matter, and foul and waste water from the district would be greatly increased.

At the present moment, there is a difficulty with regard to the drainage of several towns situate on the banks of the Thames. Some of these towns are intimately connected with the metropolis for drainage purpose; they have been heavily taxed for drainage works executed within the metropolitan area, and have a right of drainage into the metropolitan system, but in reply to applications for that purpose, they are met with the remark, "Oh, we cannot take you in, our sewers are not large

enough." Now, such a remark may be perfectly correct if it means that the sewers are not large enough to take in the rain water and the sewage also, but it is not correct to say that the sewers are not sufficiently large to take in the sewage of these towns. The western sewers, for instance, were constructed for this very purpose; if not, why were they constructed so large? First-class sewers to drain streets are ridiculous. The sewage for the western district at the present time is so small in quantity that if the streams were excluded the pumps would have comparatively nothing to do. If the agricultural drainage and streams were allowed to flow along their natural channels to the river it would reduce the expense of pumping, and the carrying capacity of the sewers for removing sewage proper would be so greatly increased, that the district of the Lower Thames Valley Joint Drainage Board might be connected with the Metropolis for drainage purposes to the great benefit of all concerned.

CHAPTER V.

A PROPOSED METHOD OF SEWAGE DISPOSAL FOR THE METROPOLIS, NORTH OF THE THAMES.

The Present Works a failure as regards the disposal of the Sewage—The effect of discharging Sewage into the River—The Nuisance from the sewage—Shoals are formed—It is desirable to reduce the quantity—UTILIZATION SCHEME—The author would cut off the Western District and make three separate Sewage Districts—PRECIPITATION SCHEME—The Sewage to be Treated with Lime at the Present Works—Depositing Tanks to be Constructed on the Marshes—The Sludge to be Utilized in the Manufacture of Bricks.

HE disposal of the sewage of London has always been a matter of difficulty, and this difficulty has not been removed by the present system of drainage. The brick work has been executed in the very best manner and the pumping machinery is a wonderful specimen of mechanical skill, but still so far as regards the disposal of the sewage, the works are insufficient and it is at present disposed of by discharging it into the river, sludge and all, without any treatment whatever. The effect of this is that the river is polluted to an alarming extent, shoals are formed which impede the navigation, and the sewage filth is constantly being cast upon the river banks. The old plan was to store

the sewage in cesspools, constructed in yards and gardens and sometimes under houses, it was next turned into the Thames, and it is by the present system moved on and turned into the river lower down. The nuisance is recurring. It has been removed but not abated, it will therefore crop up again and again unless something is done, and this is a grave sanitary defect.

In order to dispose of the sewage economically it must be brought into a small compass; as it is we have to pay for purifying, conveying, pumping and storing it, at so much per million gallons, and every gallon of water with which the sewage is diluted adds to the cost, besides that, the clean water is lost to the community.

There is no doubt but it would have been far better, in the first instance, to have divided the metropolis into separate sewage districts; for if this had been done, the quantity of sewage in each could easily have been treated and purified. There was no necessity to bring all the sewage to one point, and it was a great mistake to do so, as it is so much more difficult to treat on account of its bulk.

Utilization Scheme.

For a system of utilization the author would reopen the natural water courses and modify the

existing system so as to divert all streams from the sewers; cut off the unnatural connection between the Eastern and Western districts, and deal with the Western sewage in its own district. If that be impracticable now on account of the building that has been going on; he would pump it into the high or mid-level sewer, and if these be not of sufficient capacity he would construct a new line of sewer along Buckingham Palace Road, Victoria Street, Whitehall, St. Martins' Lane, Hart Street, Theobald Road, Old Street and Hackney Road, &c. He would make three separate sewage districts, for the high-level, middle-level, and low-level sewers the high-level sewage to be diverted and disposed of by gravitation in the direction of Leyton; the middle-level sewage to be dealt with at a lower level than the last; the low level and Western sewage to be pumped into Essex in the direction of Barking, and he would construct works to clarify the sewage with lime and afterwards purify it by passing it through the soil, as described in part II of this work.

Precipitation Scheme.

For a system of clarification only, the author would utilize the present works for the treatment of the sewage, and construct depositing tanks upon the marshes beyond Barking Creek.

For treating the sewage he would adopt the lime process, because it is the cheapest and most efficient process that has yet been employed Lime would not be injurious to the river, for it is always present in its waters, and as there are lime-kilns on the banks of the Thames, not far distant from the present outfalls, it can easily be obtained. At Birmingham the sewage, amounting to 8 million gallons per day, and at Leeds the sewage, amounting to 12 million gallons per day, is treated at each place most efficiently by the lime process.

Without going into the details of precipitation, which will be found in another part of this work, the author would separate the drift by catch-pits, remove it from the works and shoot it to waste, until some use can be found for it. The night soil and coarse floating matter he would remove by screening, and sell it for manure. For this purpose he would remove it in barges or by railway, and establish depots for the sale of it, or take land to utilize it. Part of the fine sewage mud he would pump into brick-fields, and utilize it in making stock bricks; the remainder he would pump on to the marshes to raise the ground, and afterwards utilize the ground for market gardens, or he would let the mud lay until the organic matter had rotted, when it may be removed and utilized for dressing gardens or fields. If there be no use for it, he would bank it round and

raise it to a height of 50 feet if necessary. With these means of disposal there is no pretence for saying that the sewage cannot be dealt with by precipitation on account of the quantity of sludge, for the whole of it can be disposed of immediately without loss, supposing there is no demand for it, but there is a probability of some of it being utilized at a profit. Taking the quantity of sewage at 60 millions of gallons per day, the works would only require to be about five times as large as those at Leeds.

CHAPTER VI.

THE AUTHOR'S NEW METHOD OF UTILIZING SEWAGE SLUDGE.

Sludge accumulation—Opinions of Commissioners, &c., as to its Value—Drift—Organic Matter—Sludge or Malm—The Cement Process—Invention of the Stock Brick Making Process—Importance of the Invention—Opinions of Eminent Engineers as to the Sludge Difficulty—A Profit from Sewage Sludge—A few Remarks about Brick-making

THE question of sewage purification has been perfectly solved so far as the liquid is concerned, and there is now no difficulty whatever in obtaining an effluent fit to turn into any stream or river, the water from which is not used for drinking purposes, if the sanitary authorities will only take the trouble and go to the expense.

Hitherto there has been considerable difficulty in disposing of the solids, which are extracted from the sewage for the purpose of purification, the consequence is that large quantities have accumulated at various sewage works. At Leicester there is an accumulation of about 30,000 cubic yards of this refuse. At Leeds things are no better and a large quantity of sewage mud having accumulated, and the land available for its reception being all occupied, men were recently employed to dig it

out of the pits and stack it on the sides, but still this did not prevent its accumulation. At Birmingham, the sludge is disposed of by digging it into the ground at a cost of about £1,300 per annum, for labour only, besides the cost of land which is a very considerable item, 90 acres being required every year for this purpose and if this process goes on for any length of time the surface will become one mass of sewage filth. It was at first supposed that it would rot away in two years so that the land could be used over and over again, but this is found not to be the case.

In the early stage of the sewage question sewage mud was thought to be a valuable manure and a very influential company having obtained a grant of the sewage of Leicester for 30 years, carried out their process on a large scale, but it was not a success. The manure which was estimated to be worth two guineas per ton was found to be worthless and the company were obliged to give up their magnificent works to the Corporation, to be let off their bargain. Since then other companies have been formed for the purpose of utilizing sewage sludge as a manure, by using fertilizing elements for precipitation, but they have not been commercially successful, for the manure was found to be of less value than the chemicals, which had been used for its precipitation. Other

companies have endeavoured to fortify the sludge with fertilizing chemicals, and so make it a valuable manure, but they also have been unsuccessful: sewage manures being unmarketable on account of their low value in proportion to their bulk.

Various Royal Commissions have been issued for the purpose of eliciting information as to the value of sewage sludge and the most eminent scientific men have given evidence. The following quotations from these sources are worthy of the serious consideration of sanitary authorities:—

"Comparatively few farms are so situated that they can afford the expense of carting semi-dried sewage sludge, containing from 60 to 70 per cent. of moisture from the works to their fields. The refusal to accept such sludge as a gift in not a few instances, rather shows sound discrimination than ignorance on the part of the farmers."—*Voelcker's Report, Town Sewage*, 1876.

"It appears further that the sludge in a manurial point of view is of a low and uncertain commercial value, and the cost of its conversion into a valuable manure will preclude the attainment of any adequate return on the outlay and working expenses connected therewith, and that means must therefore be used for getting rid of it without reference to possible profit."—*Society of Arts Conference, June*, 1876.

"It would appear that to learn the lesson that money cannot be made out of sewage sludge is very difficult, as over and over again it has been proved that there is no commercial value in it. The Leicester works proved this many years since, and every independent chemist of known repute has stated the fact when called upon to analyse sewage mud. Neither is this mud capable of being fortified by an admixture of chemicals, which will give it a paying commercial value. * * * * Neither the lime process nor any other existing method of precipitating sewage is likely to be commercially advantageous to those who engage in it. We consider that this is, however, not the light in which the matter should be viewed. The great problem is to get rid of sewage advantageously, to agriculture it may be; if not, at the least expense to the community at large."—*Report of Royal Commission, Town Sewage*, 1876.

Notwithstanding these difficulties, as sanitary authorities are now compelled by the Public Health Act, 1875, to free their sewage from "all excrementitious or other foul or noxious matter before it is discharged into any natural stream or watercourse," precipitation is being more and more resorted to.

The author, therefore, puts forward the following process for dealing with sewage mud and the

solids from town sewage, believing that it will meet the want which has so long been felt, better than any process that has heretofore been proposed, and if properly taken up and fairly worked with the requisite skill and appliances, it cannot fail of success.

The works proposed by the author in another part under the head of Sewage Treatment, would naturally divide the solids from the sewage of a Town, where the combined system of drainage has been adopted, into three sorts—Drift—Organic Matter—Sludge or Malm,—and as they possess different properties, he proposes to keep them separate and deal with them in three different ways, which will give three chances of disposal instead of one, and the separated materials will not only be more easy to deal with, but more valuable than when they are mixed together.

Drift.

The Drift, consisting chiefly of the coarse particles washed from the roads and streets, may, according to circumstances, be shot to waste, or washed and used for making foot paths, bottoms of roads, or similar purposes, and in some cases it may be ground and used for making mortar.

Organic Matter.

The coarse organic matter consisting of the

insoluble parts of the sewage, including night soil, paper, rags, and the fibrous and floating matter of trade refuse from the various manufactories, which is separated by the screening process, may be removed to agricultural districts, and laid in heaps to rot, along with other manure, until required for use by the farmer; or it may be decomposed and fortified with chemicals, and then dried by pressing, or in any other convenient manner, and utilized as a low class of artificial manure.

Sewage Sludge or Malm.

The term sewage sludge in this place is not intended to include the drift nor the coarse organic matter just described, but it refers solely to the finely divided insoluble particles which are precipitated by lime, after the coarse organic matter and drift have been removed. It consists of lime used for precipitation, chalk precipitated from the water, alumina from the washing of clay lands, silica from the washing of roads, and various sorts of mineral matter. As stated elsewhere, it requires $1\frac{1}{2}$ yards of lime for the treatment of $1\frac{1}{4}$ million gallons of sewage, and the precipitate is equal to 45 tons of thin sludge, containing 90 per cent. of water, and it is found that when the water supply is derived from calcareous strata, the chalk in the

sludge is equal to about four times the quantity of lime used for precipitation.

Sludge is very retentive of the water with which it is mixed, and by itself will not readily dry; if dug into the ground it does not rot but clings together, and as we have seen, it possesses no value as a manure, but partakes very much of the character of the malm or washed clay and chalk, which is used in the neighbourhood of London in the manufacture of stock bricks, and it was from a knowledge of these and other facts that the author arrived at the conclusion to utilize it in that way. He is aware that it has been used in the manufacture of cement, but if you can make cement from sewage sludge you can also make stock bricks and if the cement process be successful the brick-making process will be much more so; all the advantages are on the side of the brick-making, and what is good in the former process is also good in the latter. Portland Cement is made with 65 per cent. of chalk and 35 per cent. of clay, and bricks are made with lime and clay in the following proportions:—Malms, 33 per cent. chalk, 67 per cent. clay; Washed Stocks, 22 per cent. chalk, 78 per cent. clay; Common Stocks, 11 per cent. chalk, 89 per cent. clay. The organic matter in both cases is consumed, and there is a complete chemical change. The brick is semi-vitreous and if the

burning is continued it runs to slag, the substance so formed being similar to blue bottle glass.

In order to make good cement the mixture of lime and clay must be combined in pretty accurate proportions, but sewage sludge is a most uncertain mixture and the quantity of lime in it being subject to considerable fluctuation, renders the process of cement making uncertain; and the material must be dried. There is not this difficulty with the brick-making process, because the quantity of lime may vary from 11 to 33 per cent. and yet the bricks will be equally good; it is only a question of sorting them after they are made. Then as to the moisture in the sludge it is costly and difficult to evaporate in order to make cement, but to make bricks it can be utilized to temper the clay, as a considerable quantity of moisture is required for that purpose.

The above remarks are made with a view to comparison and not in any way to disparage the cement process. But every step taken by the author confirms him in the belief that there is a great future for the brick-making process in utilizing sewage sludge, because the proportions do not require to be accurate in order to obtain a good result; because it surmounts the difficulty of drying the sludge, because no skilled labour is required to carry on the process beyond what is to be found in

any brick-field and because it is most generally applicable.

Brick Making.

The following extract from the minutes of proceedings of the Institution of Civil Engineers, Vol. 61, issued August, 1880, so well describes this process that it is given at length.

"Mr. E. Monson exhibited various samples of bricks made from sewage sludge. Being one of the engineers who had received instructions to prepare plans for disposing of the sewage of the Lower Thames Valley, his scheme, as well as those of other engineers, had been reduced to a common standard, and it was debited with the sum of £48,000 as the capitalised cost of treating the sewage with lime, previous to its being passed through the soil by intermittent filtration. This led Mr. Monson to consider how he could utilize the sludge and reduce the annual cost of treatment. Almost adjoining his residence there were a number of brick-fields, and in order to make stock bricks it was necessary to mix chalk with the clay. This chalk was brought from a distance at great expense, and was ground with water and mixed with the clay. For the better class of bricks, the cost of the chalk and grinding was 6s. per 1,000; for the common stock bricks the cost was 2s. per 1,000. The semi-liquid mass of

chalk and clay was called malm. It occurred to him that the sewage mud precipitated with lime was similar to this mixture of clay and chalk, and that it might be utilized as a substitute for malm in the manufacture of stock bricks. He accordingly procured some sewage sludge, mixed it with clay, and made it into bricks, some of which had been burnt in a kiln, and some in a clamp. The kiln-burnt bricks were hollow and husky, because the materials had not been properly mixed, and because they had not been properly put together by clot moulding before making. The clamp-burnt bricks were better, but they were all burnt to rough stocks except one brick, and that was a fine colour, though from the faulty moulding it lacked density. He continued the experiments, and had succeeded beyond his most sanguine expectations; at every stage he improved on the last. The colour of the bricks did not depend so much upon the clay as the way in which the bricks were burnt. If properly burnt in a clamp they would be yellow stocks; if burnt in a Scotch kiln, they would be red; if the heat was increased and the bricks close bolted, they would frequently be white or grey; and if burnt in a kiln or oven, such as was used for burning Staffordshire blue bricks, they would be blue. The yellow colour and the white were owing to an intense heat, the admixture of chalk, and the bricks being close bolted

for burning. The red colour was due to the bricks being burnt at a low heat with a free supply of air; the blue, to the bricks being burnt with an intense heat, and deprived of air. If sewage sludge was made into stock bricks the materials were changed; the lime in the sludge combined with the silica and alumina in the brick earth forming a silicate of lime and alumina, and if properly burnt was converted into a rough sort of glass. The organic matter was completely decomposed. The bricks, being burnt with ashes, would in some towns effect a saving of 8s. per 1,000 bricks; and the ashes, which in many towns were shot to waste, could be thus utilized and profitably disposed of. The discovery in London a century ago, that town ashes could be utilized for burning bricks in clamps was a most important event. Once the clamp was lighted, it continued to burn without attention, except to shelter it from the wind, and the bricks remained in the clamp until they were required. In utilizing sewage sludge in the manufacture of bricks much depended upon having the materials intimately mixed and well put together, and this was what an ordinary workman would seldom do if the bricks were made by hand, but there was no difficulty if they were made by machinery. The machine-made red bricks, consisting of two parts of Leeds sewage sludge and one part of shale, were manufactured at Mr. Wray's

brickworks, Leeds. The sludge, when nearly dry, was mixed with the shale, and tipped into a perforated pan, the bricks being manufactured without any further handling, except by a boy for additional pressing. One thousand two hundred bricks were made in this way in two hours from the time of commencing. They were burnt in a close kiln, which had a steam flue at the top, connected with a tall shaft. When the steam was driven off the steam port was closed, and a connection with the shaft was opened from the bottom of the kiln."

"Amongst the sanitary appliances, we noticed some model samples of bricks made from the sewage sludge of Birmingham, Leicester, Windsor, and Ealing. The patentee is Mr. Monson, C.E., of Acton, W., and he claims for his invention that it is not only an efficient but a profitable method of disposing of sewage sludge and town ashes. The bricks were of various colours, exceedingly well made, perfectly sound, and adapted to clamp and kiln burning. Mr. Monson's process completely removes all difficulty in disposing of sewage sludge; and as it turns to profitable account what is now a source of vexation and expense to sanitary authorities, we shall probably soon hear of its extensive adoption; and we should particularly commend it to the attention of the Metropolitan Board of Works, as one means of utilising the sewage sludge which is now

daily poured into the Thames."—*Extract from the "Sanitary Register," 6th June*, 1879.

At Birmingham, 53,000 bricks were made and sold at market price, and it was found that a superior white brick could be made by adding one-eighth of sewage sludge to marl, which ordinarily burns red. At Leicester, bricks have been burnt in kilns and clamp, and the result shows, that with proper appliances the process will be a great success.

The importance of this invention may be gathered from the discussions upon the sewage question which have taken place at the Institution of Civil Engineers, and the following are some of the opinions then expressed.

"Apart, however, from this financial objection there is a formidable practical difficulty attaching to the use of these processes [precipitation] which up to the present time has proved an almost fatal bar to their efficient operation, namely, the difficulty of dealing with the enormous quantity of sludge developed by the employment of precipitants."—*Mr. N. Bazalgette.*

"The chemical processes, hitherto applied to the purification of sewage, depended essentially upon the production of certain solid compounds within the body of the sewage, which solid compounds carried down with them the suspended matter of the sewage, and a certain small proportion, varying with the

quantity of the solid so deposited, of the polluting matters in solution. The principal solid matters thus produced within the body of the sewage were carbonate of lime, alumina, oxide of iron, and carbonate of magnesia. There was also the phosphate of alumina, which however, did not differ in its character from the other materials. These chemicals were nearly identical with the chief constituents of the earth's surface."—*Dr. Frankland, Minutes of Proceedings of Civil Engineers, Vol.* 48.

"In conclusion, it ought not to be supposed that intermittent downward filtration got rid of the most difficult portions of sewage, namely, the sludge."—*Mr. Hy. Law.*

"The information obtained during the last few months showed distinctly that the sewage question resolved itself into the difficulty of the disposing of the solid matters in suspension. The difficulty of treating the sludge by chemical processes was notorious. In irrigation and filtration it was the solid matter in suspension that fouled the carriers and the land and blocked up the pores of the filtering material."—*Mr. Shelford.*

"The great difficulty attending the chemical processes for treating sewage was that in such treatment an enormous quantity of semi-liquid sludge was produced. When removed from the tanks this sludge contained 90 per cent. of water, and it was the

separation of the solid material from this water which constituted the difficulty. The removal of the water of the sludge, either by drying or by any plan of filtering, was attended with both trouble and expense. The production of useful manure out of this sludge at a moderate cost, was, he believed, out of the question."—*Mr. T. W. Keates.*

"The aim of the chemist should be to provide a cheap precipitant which would keep down as much as possible the bulk of the precipitate. The great difficulty in connection with all the tank processes, was the disposal of the sludge, and the less the precipitating agent itself added to the quantity of this the better. Such a process as that, of digging in the immense quantity of sludge produced by the lime process at Birmingham, was unlikely to be of long duration."—*Mr. James Mansergh.*

"The greatest difficulty in dealing with raw sewage next to its bulk and highly diluted condition was caused by the slimy organic matter which raw sewage contained in a state of suspension. These suspended matters, and not the matters in solution, were the cause of most soils becoming sewage sodden. Remove the suspended matters, and half the difficulty of the disposal of sewage would be solved. Unfortunately the removal of the matters in suspension entailed expenses."—*Dr. Voelcker.*

There are difficulties in introducing this or any other process.

FIRSTLY. Because so many things have been tried and failed.

SECONDLY. Because sanitary authorities are waiting for some miraculous invention that shall supplant all others and enable them to dispose of their refuse without trouble or expense.

THIRDLY. Because there are vested interests to contend with. Brickmakers are averse to an additional quantity of bricks being made, and the farmers, superintendents or managers of sewage works, as a rule, wish things to remain as they are.

If this process be taken up by the sanitary authorities themselves, and fairly worked, they will make a profit where they now sustain a loss; they will get rid of the nuisance from the present accumulations and save the cost of ground for its storage; and they will find that they are not only able to utilize the sewage mud and town ashes in the manufacture of bricks, but also the clay and marl from the various excavations for laying pipes and sewers in their district, which is now shot to waste; and as good stock bricks are superior to all others for engineering purposes, many of the bricks made by the authority can be used in their own works to the great advantage of the ratepayers in point of economy, and the making of bricks must not be regarded from a brickmaker's point of view, because its primary object is to utilize and

dispose of sewage mud; a product which at present has not a marketable value.

The burning of bricks in clamps in the neighbourhood of London, effects a saving of about 6/- per thousand as compared with kiln burning, and on the Northern side of London where chalk is difficult to obtain, it is estimated that the use of sewage sludge instead of chalk for making malm bricks, provided the sludge were delivered direct into the brick field, would effect a saving of 6/- per 1,000; for washed stocks, 4/- per 1,000; for common stocks, 2/- per 1,000.

Bricks are made from a variety of materials according to the district, the principal of which are mild clay, galt, marl, shale and blue bind. They are mostly burnt in kilns, but the London stocks are invariably burnt in clamps.

Sewage sludge can be utilized in the manufacture of every kind of brick, but as it is best suited for the manufacture of stock bricks, that process will be described more in detail.

Stock bricks are principally made in the neighbourhood of London, and the process was invented for the purpose of utilizing the refuse of dust bins many years ago, but it is not known when it was invented nor by whom. The brick earth is dug in winter turned over and exposed to the weather; a mixture of clay and chalk which

has been reduced to slurry in a wash mill, is run upon it by means of shoots. The quantity depends upon the quality of the brick it is intended to make, only a small quantity being required for common stocks. The whole of the clay and chalk used for making the best bricks, which are called malms, should be washed. Fine ash in the proportion of about three inches in depth of ash to one foot in depth of prepared earth, is mixed with it to burn the bricks and to keep them from shrinking whilst drying.

"The object of adding chalk to the clay is two-fold. In the first place it acts mechanically in diminishing the contraction of the raw brick before burning, and in the second place it acts as a flux during the burning, combining with the silica of the clay, so that a well-burnt London brick may be described as a silicate of lime and alumina, and therefore differs greatly from an ordinary red, kiln burnt brick, made of pure clay without lime or alkaline matter, the silica and alumina of the brick-earth being in the latter case merely in mechanical and not in chemical combination."—*Dobson Brick and Tile Making.*

For the utilization of sludge the materials may be prepared by taking the brick earth from bank; adding the sludge and ashes and grinding the whole in a nine feet solid bottom pan, so that lumps

in the sewage may be completely broken down, and it is very important in this process that the materials should be thoroughly mixed and ground as fine as possible. A perforated pan is very convenient to use with a brick making machine, but the materials must in that case be dried, or they will not pass through the holes in the bottom of the pan.

METROPOLITAN SEWAGE AND WHAT TO DO WITH IT.

PART II.

SEWAGE PURIFICATION IN THEORY AND PRACTICE.

LONDON.
PRENTICE & MONSON, 47, UPPER THAMES STREET, E.C.

SEWAGE PURIFICATION IN THEORY AND PRACTICE.

CHAPTER I.

CULTIVATION OF THE SOIL, THE DISCOVERY AND USE OF ARTIFICIAL MANURES.

Preparation of the Soil—Drainage and cultivation alters the character of the Soil—Various kinds of Vegetable Life—Three kinds of cultivated Plants—Plant Food—Farm Yard Manure—Town Manure—Artificial Manure—Phosphatic; Nitrogenous; Potash; and Soda Manures—Lime—Gypsum—Carbon.

AVING dealt with the subject of sewage collection in the first part of this work, we now come to the question of sewage disposal or what to do with it, and we naturally enquire if it can be applied to the soil as a manure and with benefit to the farmer. In order to settle this point we shall briefly direct attention to the cultivation of the soil, but so far only as it bears upon the question of sewage disposal.

In ordinary farming the land is prepared for crops by digging, ploughing, harrowing, and rolling, to lighten it up and let in the air, and it

must be properly drained: the condition of the soil being most important, because, if you change its character by cultivation, drainage, or other means, it will support a different kind of plant; thus, if you embank a stream so as to make the adjoining land wet and swampy, it will grow water plants, but if you put in drains so as to lay it dry, the water plants will die from want of food. As an illustration of this the author begs to narrate the following curious facts which were observed by him whilst surveying Pewit Island in Essex. Nearest the water, the ground was soft mud, upon which persons could only walk with mud splashers; at a higher level were little knots of moss, these would bear the weight of a man without much danger of sinking; at a still higher level the ground became firmer, and grew samphire; and when still firmer, lambs-ears; when yet firmer, grass; and the state of dryness of the ground could always be told by the growing plants. Fresh-water plants will die if watered with salt or brackish water, as is experienced at Harwich, where the inhabitants find it necessary to water their pot flowers with rain water in consequence of their well water being brackish.

There are various sorts of vegetable life, each of which requires a different kind of food and a different condition of the soil, viz:—Land plants, which require only a moderate quantity of water

for their subsistence—Water plants which grow in fresh water, and—Marine plants which grow in salt water.

Cultivated plants may be roughly divided into three classes:—Potash plants, which include beet, mangold wurtzell, turnip, and maize—Lime plants, which include clover, beans, and peas—Silica plants, which include, wheat, oats, barley, and rye.

PLANT FOOD.

Every plant requires its special kind of food, which must not only be placed within its reach in sufficient quantity but it must also be properly prepared, so that it is easy for the plant to digest. For example, granite is composed of silica, alumina, lime and potash, which are constituents of a fertile soil; in its earlier stage of decomposition, this rock will only grow moss, stone-crop and similar plants, but when more decomposed it forms a soil suitable for cultivation; the elements of food for plants were there in abundance previously to the decomposition of the rock, but they were not properly prepared for assimilation, and plants so situated would die, notwithstanding that the elements of food were within reach. The same may be said of the coprolite, which is of no use as food for plants until it has been reduced to powder and rendered soluble by chemical treatment.

The roots of plants have the power of absorbing from the soil the mineral and organic matter which have been rendered soluble: and every crop extracts therefrom a certain amount of fertilizing elements, which exist there in a state fit for the food of plants, in limited quantities only, it is therefore necessary to manure the land, in order to restore the elements, which have been abstracted from it by the crops that have been grown, because, if these be not replaced it will become unproductive.

FARM YARD MANURE.

Most of the elements required for crops are as a rule abundant in the soil, and only potash, phosphoric acid, and the nitrogenous elements require to be replaced. These elements were formerly obtained from farm yard manure, which consists of decayed vegetable matter such as straw used to litter the farm yard, the stalks and leaves of plants, and the excrement of animals. It contains ammonia, phosphate of lime, potash, carbonic acid, and various saline and mineral ingredients, and when applied to the soil in a state of decomposition, restores the elements taken therefrom by the crops, and acts upon it so as to fit it for vegetable growth. Potash was also formerly obtained from the ashes of wood, &c., which had been used for fuel.

TOWN MANURE.

Town manure would at one time fetch from 5s. to 10s. per waggon load, and farmers who did not keep much stock depended very much upon it; but the introduction of the water-closet system deprived them of this supply.

"The fertilizing and commercial value, of sewage sludge and of portable manures prepared from sewage; night soil manures; and of common farm-yard manure; chiefly depends upon the proportions of phosphate of lime, potash and nitrogen, which these fertilizers contain. These fertilizing constituents of manures can be bought at the present time in the form of concentrated artificial manures, such as guano, bone dust, sulphate of ammonia, &c., at the following rates:—Phosphate of Lime @ 1d. per lb. Potash @ 2d. per lb. Nitrogen calculated as Ammonia @ 8d. per lb. I need hardly say that in such concentrated forms, phosphate of lime, potash and ammonia, have a much greater value than they possess in the shape of manures the bulk of which mainly consist of materials without value, and occurring in abundance in almost every kind of soil. Nitrogen occurs in these, in the shape of nitrogenous organic matter, in which form it is less valuable than in the form of ready formed ammonia. In estimating the theoretical value of sewage and similar bulky manures,

nitrogen is assumed to be present in the form of ammonia, or to have the same value as the nitrogen in the salts of ammonia; this is a mistake, and the nitrogenous constituents of sewage are thus valued at too high a rate, and do not fairly represent their commercial value."—*Dr. Voelcker.*

ARTIFICIAL MANURE.

In the practice of his profession the author has heard the lamentation that the soil was being exhausted by the present extravagant style of farming, and that the land would soon become impoverished and unproductive. In some parts of Suffolk he has seen the grass borders round the fields which were said to have eked out the fertilizing matter in the soil by being ploughed in. He knew that the farmer was deprived of his supply of potash from the burning of coal instead of wood ,and from the using of soda for washing instead of potash; that his pastures were ploughed up, and his cows gone that used to supply him with manure—only two cows being now kept at farms where there were formerly 40; that his supply of manure from towns, ran short in consequence of the new method of removing town refuse by suspension in water: and yet with all these difficulties to contend with the farmer was not ruined, nor was his land im

poverished, and he set himself to enquire how this could be, and how he could possibly do without sewage: and he found that the farmer had been calling in the aid of science whilst looking about for other supplies, and, that his efforts had been crowned with singular success, resulting in the discovery and manufacture of artificial manure.

In connection with this, agricultural chemistry has made great progress during the last few years, which, coupled with the introduction of artificial manures, has completely revolutionized the system of farming. By the aid of geological and chemical science a farmer can now ascertain what elements are taken out by the crops and require to be replaced—what materials are abundant in the soil —what deficient, and what can be put therein to make it more productive; for Chemistry in agriculture shews the true constitution of various plants and establishes the value of organic as well as inorganic manures.

It is found from analysis that the constituents of plants are of two kinds, atmospheric or organic elements, and mineral or earthy elements, and that if a plant be burned, the organic matter is consumed, whilst the ashes which remain, represent the mineral matter which has been taken from the soil. Chemists having determined the various constituents of plants by analysis, tables have been published

which show the exhaustion of the soil by the most generally cultivated crops on a fair average, and how they can be replaced.

By using artificial manures a farmer saves in price, saves in cartage, and saves in labour, he can put into the soil just the kind of food required by the crop, or he can increase its fertility by adding to it one or two elements which are least abundant.

PHOSPHATIC MANURES.

Phosphorus is found in volcanic and other rocks in a state of phosphoric acid, in union with bases, chiefly lime and magnesia, which crumbling down, form our fertile soils, and in the coprolite found in Suffolk, Cambridgeshire, and Bedfordshire, which is a stone-like substance and supposed to be the petrified dung of animals. It is a constituent of plants used by man and the domestic animals as food, and occurs in grain, peas and beans, in the form of calcareous phosphates, and in a peculiar state of combination with carbon, oxygen, hydrogen, and nitrogen. It exists in animals in the flesh, tissues, brain, milk and secretions, and their bony skeletons owe their strength and rigidity to the phosphates of lime and magnesia. Superphosphate manure is manufactured from bones, coprolite, phosphatic rocks and earths, which are ground to

powder and treated with sulphuric acid; and also from the cheaper guanos; its value depends upon the quantity of phosphoric acid which it contains, and whether the acid is free or in combination, soluble or insoluble. It is the only manure required for land in good heart. For a beet crop, and for poor land it should be used with the sulphates of potash and ammonia, and for corn plants with phosphate of magnesia and ammonia: the action of these manures is said not to be so quick as those containing nitrogen.

NITROGENOUS MANURES.

Nitrogen constitutes four-fifths of the air by volume, and is present in the nitrates of potash and soda, coals, and other minerals, and is a constant ingredient of plants and animals. The nitrogen of decaying animal and vegetable matter is discharged into the atmosphere in the form of ammonia, and agriculturists attach great importance to this class of manures. It was at one time contended on high authority, that plants could obtain all the necessary ammonia from the air, and that only mineral constituents need be put into the soil, but this has been disproved by scientific men and by the general practice of agriculturists. Ammonia is obtained from urine and the ammoniacal liquor of gas works. It is volatile, very soluble in water, and in its

gaseous state readily combines with carbonic acid, and forms the volatile salt carbonate of ammonia. Amongst this class of manures may be mentioned guanos, nitrate of soda, sulphate of ammonia and animal refuse. Ammonia and its compounds being very soluble in water, if sulphate of ammonia or guano be applied in autumn, and a wet winter follows, much of the nitrogen will be converted into nitrates, and being carried down into the ground will be lost to the crops.

POTASH MANURE.

Potassium occurs in nature abundantly, but solely in combination, and chiefly as potash; it is found primarily in granite, trap, and other igneous rocks, associated with different bases; and potash in the condition of a silicate, forms nearly one-sixth of felspar, a well known constituent of granite; it occurs also in small quantities in animals, in natural waters and in the sea. Growing plants extract it from the soil in very large quantities and when they are burned it forms a chief ingredient of their ashes, but where the crops and straw are not sold off the farm, no potash is needed to compensate for the exhaustion of the soil produced by the crop. The Potash manures are muriate and sulphate of potash and kainite, and they may be applied with advantage to potatoes, clover, beet,

and turnips. Soda is a much less fertilizing constituent than potash, and although the same class of manures may sometimes be used the one for the other, soda cannot replace potash in vegetable economy.

LIME, GYPSUM AND CARBON.

Lime has a dissolvent and stimulating action, and is especially useful in reclaiming peat or bog earth, as it decomposes the excess of vegetable matter, and renders the soil more open. Gypsum is the most generally useful manure to apply to leguminous crops, at the rate of 4 or 5 cwt. per acre.

Carbon is the base of carbonic acid and the most considerable element of the solid parts of minerals and vegetables. The carbon of plants is principally obtained by the direct action of the leaves of the plants upon the atmosphere.

CHAPTER II.

THE VALUE OF SEWAGE CONSIDERED THEORETICALLY AND COMMERCIALLY.

Erroneous Notions as to the value of Sewage—It is unsuited for ordinary crops—Sewage compared with manures—The Conclusion come to is that it has not a Commercial Value—Sanitary Authorities must pay for Sewage Disposal.

ERY erroneous notions have existed as to the value of sewage, and there is a great difference between its theoretical and commercial value. In 1874 the author read a paper on the Sewage Question before the Association of Municipal and Sanitary Engineers and Surveyors, at their first annual meeting at the Sewage Congress at Birmingham.

At that time sewage was considered to be of great value, but the author after examining fact after fact, had arrived at the conclusion that the value of sewage was simply ideal; that notwithstanding its theoretical value of 2d. per ton, it would not pay the expenses of removal, that in fact it had no commercial value whatever; he hesitated to express this opinion and fully expected it to be controverted, but it was received with approbation and endorsed by the meeting. "It is very important"

said the author "that this question of value should be settled—because if sewage be a valuable manure, as some assert it to be, it will pay to lay out large farms and avail ourselves of its fertilizing properties, but if it be of no value we shall go to just so much expense as will be necessary for purification only,—simply taking as much land as is sufficient for that purpose, and getting rid of the sewage in the cheapest way. Sewage has not a commercial value. If it has, why is the sewage of London, said to be of the enormous value of upwards of one million pounds sterling per annum, allowed to run to waste? Where are the applicants for the sewage of our large towns? Why are our farmers spending thousands of pounds in guano and other artificial manures, whilst the worth of millions of pounds sterling of sewage is running to waste? How is it that capitalists do not invest their money in sewage farms and sewage works? Have the people of England no enterprise, or are they blind, and do not perceive this mine of weath? How is it that neither farmer, chemist, nor engineer can get a value out of it; and why are sanitary authorities obliged to take land compulsorily for the disposal of it? These questions admit of but one answer, which is that the sewage is of so little value as a liquid manure that it cannot be utilized at a profit."

Sewage saturates the soil, alters its character, unfits it for growing ordinary farming crops, and the English farmer whose crops frequently suffer from an excess of moisture would rather be without it. As a liquid manure it is very weak, and although it can be used for growing root crops and to increase the quantity of green food for cattle, it is for this purpose, according to *The Builder*, found to be little better than water.

"The highest returns claimed from the use of sewage manure have been at the rate of from £32 to £40 per acre. We find that the growth of Italian rye grass amounting to seven tons an acre is stated to have been produced. If we took last year's price for hay this would give a higher value, but that may be considered as exceptional—£31 10s. would be the return for the hay at £4 10s. per ton. In water meadows, without manure, or with an occasional top dressing of bone dust, that will not amount to more than 14s. per acre per annum, crops of five tons per acre, including that which is eaten on the ground, are about the maximum. There is little doubt that these may be materially augmented by such a disposal of the irrigation as should avoid the present wasted area of innumerable water carriers. But it is possible this may cut both ways, so that we take the difference of yield between the ordinary water meadow and the sewage farm at

two tons of hay, say £9 per annum. This is therefore the total produce of the application of a quantity of sewage averaging in the value hitherto nominally attributed to it at from £6 10s. to £312 (at Merthyr the sewage from 1,100 souls is applied to an acre of ground, and the fertilizing elements according to theory are of the value of £312). That the effluent water from sewage must go through the ground to be purified we take to be an undoubted maxim in the present state of sanitary science. But we complicate this problem, in itself not a simple one, by attempting to derive from sewage, materials fitted for the food of plants which do not exist in it, in a state in which plants can assimilate it, and which we cannot convert into such a state. We go in the wrong direction."—*The Builder* Oct. 19th, 1872.

In the neighbourhood of the metropolis and large towns there is a considerable amount of manure which can be had almost for the carting, and growers taking their produce to market load back with it. This manure is applicable to all sorts of crops, can be conveyed in carts to any distance, and can be applied to a farm not specially laid out. Whilst on the other hand, sewage is almost limited in its application to root and green crops, and as a railway car can only run as far as the rails are laid, so sewage can only be applied to the land as far as the

pipes are laid, or the carriers constructed: The former applied in a state of decomposition and fermentation gives off gases, which, acting upon various bases liberate elements already in the ground, lightens it up, and lets in air to the roots of the plants: The latter cakes the ground, seals up its pores, and prevents the air getting in, the one decomposes slowly and keeps up a constant chemical action, the other sinks at once into the ground and its action upon the soil and crops is passing and transitory.

As compared with artificial manure, sewage is of enormous bulk but the whole tendency of modern farming is to reduce the bulk by applying artificial manure in a highly concentrated form.

From a consideration of the above facts, the author concludes that sewage cannot be utilized at a profit, that its value is theoretical not commercial, and that sanitary authorities must pay for its disposal

CHAPTER III.

IRRIGATION—SEWAGE FARM—FILTRATION AREA.

Irrigation, when and where Practiced—Sewage Irrigation to Purify Sewage—Sewage Farm—The Situation Important—The Soil must be of a Permeable Character—The Crops usually Cultivated upon a Sewage Farm—Filtration Area.

HE application of water to the soil for the purpose of assisting the growth of plants, has been practiced from the earliest ages, in Assyria, India, China, Egypt, France, Spain, Italy, and in the south-western counties of England. It is commonly applied to meadows, either natural or artificial, and as irrigation develops the growth of the leaves at the expense of the fruit or grain, cereal crops are, as a rule, excluded from irrigated districts.

Sewage irrigation is for the purpose of purifying the liquid which has been employed for the removal of town refuse, and to utilize it in growing suitable crops, and the sewage intended for this purpose should be clarified or filtered, because if untreated sewage be used it is found in practice that the insoluble portions and undecomposed organic matter are deposited on the ground, and giving off offensive

after passing it through the soil upon the intermittent principle, discharge it into the stream below Teddington Weir.

SCHEME A.

Your district being divided into two parts, I call one the Northern and the other the Southern Division and treating each division as a separate district I propose to construct separate works and I have selected two points of outfall but have not derived so much advantage from this arrangement as I expected.

Northern Division.

The site of the proposed works marked A on plan is situate in the parish of Isleworth in the bend of a stream to the south of Mogden Lane. It is an isolated spot and so out of the way as not to interfere with any valuable residential property. The land in the neighbourhood is suitable for intermittent filtration, and the whole of the sewage and sludge can be utilized in the numerous market gardens thereabouts. There is plenty of room for extension and the land is of comparatively low value and will not require to be diverted from its present uses. The sewage from the parts coloured green upon plan must be lifted by pumping 55 feet, but from the parts coloured brown it will flow into the tanks by

gravitation. The level of the tanks is 38·00. For the purpose of these estimates the calculations are all for cylindrical sewers.

The main sewer commences at Barnes boundary at 0·00 which is the level of Ordnance datum and has a uniform fall of five feet to the mile. The diameter at its commencement is three feet and at its termination six feet. The level at which it will receive the sewage of Mortlake is—7·50. Richmond —13·00, Isleworth—18·00. The river will be crossed by an iron cylinder of six feet internal diameter. There will be 15 inch pipe branch sewers to Kew and Ham; the level at which it will receive the sewage of Kew is—2·00, Petersham 6·50, Ham 15·00.

Southern Division.

The site of the proposed works marked B on the map, is situate on the Upper Ham Road to the North of Kingston, and the land in this locality is suitable for intermittent filtration. The level of the tanks is 27·00. The sewage from the parts coloured green must be pumped up 32 feet, but from the parts coloured brown it will flow into the tanks by gravitation.

The low level sewer commences at the boundary of West Moulsey at 26·00 and has a uniform fall of six feet to the mile. The diameter of the sewer at commencement is two feet and at its termination

The crops usually cultivated upon a sewage farm are Italian rye grass, cabbage, savoys, kale, mangold wurtzell and beet. Oziers are grown upon the filtration areas, and watercresses in beds laid out for that purpose. Sewage has also been utilized to a limited extent in growing celery, potatoes, onions, carrots, cucumbers, vegetable marrows, asparagus and rhubard. But the application of sewage to the soil in large quantities entirely alters its character, so that crops grown upon sewage farms for profit, are limited to those which require a great deal of moisture.

"Italian-rye-grass is probably in all respects the most advantageous crop to be grown under sewage, as it absorbs the largest quantity of sewage, occupies the soil so as to choke down weeds, comes early into the market in Spring, continues through the Summer and Autumn, bearing from five to as many as seven cuttings in the year, and producing from 30 to 50 tons of wholesome grass upon each acre. The area placed under this crop must, however, have reference to local means of consumption, as the young grass will not keep nor bear long carriage. It is most profitable for feeding milch cows. A dairy and a sewage farm should therefore, whenever practicable, be associated. In a dry and warm Summer

good hay may be made, which will be sweet and wholesome."—*Modes of treating Town Sewage.*

FILTRATION AREA.

Intermittent downward filtration differs from irrigation in that the primary object is not the profitable use of the irrigated land, but the purification of the sewage on the smallest possible area, and there is a very great difference between utilizing sewage for fertilizing land, and utilizing a portion of land for disposing of sewage.

CHAPTER IV.

THE AUTHOR'S SCHEME OF DRAINAGE AND SEWAGE DISPOSAL FOR THE LOWER THAMES VALLEY, WITH ESTIMATES OF COST, BEING A COMPLETE SCHEME OF SEWAGE CLARIFICATION AND PURIFICATION.

Difference of opinion as to the best method—The author divides sewage purification into two stages—SCHEME A—The District divided into Northern and Southern Divisions—Site of Works—The Sewers, &c.—SCHEME B—Site of Works—The Sewers, &c.—Clarification of the Sewage—The Lime process—The Sewage Works—The Tanks—Size of Tanks—Working the Tanks—Sludge—Purification of Sewage by Oxidation—Filtration area—How laid out and worked—The office which Land performs in Purifying Sewage—What is pure Water?—The Theory of Sewage Purification—Substances which are formed by the Decomposition of Sewage—Many mistakes made from not being acquainted with this theory—Various statements as to the quantity of Sewage that may be put upon an Acre of Land—Detailed Estimate of Lower Thames Valley Scheme A—Detailed estimate of Scheme B—Estimate of the annual cost of Works.

HERE is still a difference of opinion as to the best method of treating sewage, but the author as before stated, having arrived at the conclusion that it had not a commercial value, proposed in the paper before referred to, to divide sewage purification into two stages; the insoluble elements to be dealt with in the first stage by precipitation, and the soluble elements and organic matter in the second stage, by oxidation.

This method of purifying sewage is so fully described in his competition scheme for the drainage and disposal of the sewage of the Lower Thames Valley, that he ventures to submit a copy of that report with a few additions as an exemplification of the system of purification which he recommends, and if this process be fully carried out, there is no difficulty in rendering sewage sufficiently pure to be turned into any river or stream. Purification must therefore be regarded simply as a matter of expense. The report is as follows :—

REPORT upon the Main Drainage of the Lower Thames Valley, by EDWARD MONSON, Assoc. M. Inst. C.E., Acton, W., accompanied by Plans, Sections and Estimates.

June 29th, 1878.

TO THE LOWER THAMES VALLEY MAIN SEWERAGE BOARD.

GENTLEMEN,

I beg to Report that I have prepared two schemes for your consideration, marked respectively A & B, and in both cases I propose to cut off the sewage from the Thames by an intercepting sewer, receive it into tanks, clarify it by precipitation, and

after passing it through the soil upon the intermittent principle, discharge it into the stream below Teddington Weir.

SCHEME A.

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Northern Division.

The site of the proposed works marked A on plan is situate in the parish of Isleworth in the bend of a stream to the south of Mogden Lane. It is an isolated spot and so out of the way as not to interfere with any valuable residential property. The land in the neighbourhood is suitable for intermittent filtration, and the whole of the sewage and sludge can be utilized in the numerous market gardens thereabouts. There is plenty of room for extension and the land is of comparatively low value and will not require to be diverted from its present uses. The sewage from the parts coloured green upon plan must be lifted by pumping 55 feet, but from the parts coloured brown it will flow into the tanks by

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The main sewer commences at Barnes boundary at 0·00 which is the level of Ordnance datum and has a uniform fall of five feet to the mile. The diameter at its commencement is three feet and at its termination six feet. The level at which it will receive the sewage of Mortlake is—7·50. Richmond —13·00, Isleworth—18·00. The river will be crossed by an iron cylinder of six feet internal diameter. There will be 15 inch pipe branch sewers to Kew and Ham; the level at which it will receive the sewage of Kew is—2·00, Petersham 6·50, Ham 15·00.

Southern Division.

The site of the proposed works marked B on the map, is situate on the Upper Ham Road to the North of Kingston, and the land in this locality is suitable for intermittent filtration. The level of the tanks is 27·00. The sewage from the parts coloured green must be pumped up 32 feet, but from the parts coloured brown it will flow into the tanks by gravitation.

The low level sewer commences at the boundary of West Moulsey at 26·00 and has a uniform fall of six feet to the mile. The diameter of the sewer at commencement is two feet and at its termination

five feet. The level at which it will receive the sewage of East Moulsey is 21·00, Thames Ditton 13·75, Long Ditton 11·03, Surbiton 7·00, Kingston 3·50. At Kingston to the north of the Railway, a branch sewer 2 feet 6 inches in diameter crosses the river Thames to Hampton Wick and the level at which it will receive the sewage from that part is 0·00, the level of Ordnance datum, Teddington 6·00, Hampton 14·00; the fall of these sewers is eight feet to the mile. There is also a branch sewer which contemplates the inclusion of Hersham, the sewage of which would be received at 31·00 and the sewage of Esher at 24·50, the size of the pipe is 18 inches.

The high level sewer commences at Hare Lane 56·00 above Ordnance datum, it has a uniform fall of five feet to the mile and enters the tanks at 27·00, at the commencement it is 18 inches in diameter, and at its termination 3 feet. This sewer at the present time is not much required, but hereafter it may become important and the line should be preserved. There is a branch sewer to Hook which contemplates the inclusion of Worcester Park, the sewage of which would be received at 56·00. The sewage of Hook would be received at 90·00, Kingston Rural 77·50, Long Ditton detached 47·00, New Malden 37·00; the size of the pipe is 12 inches at Hook and 18 inches at Norbiton.

SCHEME B.

As an alternative scheme I propose to have only one main sewer with branches, and only the one site for the works and pumping station at Isleworth as before described, and coloured pink upon the plan. The main sewer for Barnes, Mortlake, Richmond, Kew and Isleworth, will be as before described. The main sewer from West Moulsey to Richmond Junction will have a uniform fall of five feet to the mile. The size of the sewers will be as before described until after it enters Kingston. At the Hampton Wick Junction the diameter increases to five feet which continues through Ham and Petersham. The level at which it will receive the sewage of West Moulsey is 25·00, East Moulsey 21·50, Thames Ditton 15·50, Long Ditton 14·00, Surbiton 11·00, Kingston 2·50, Teddington 2·50, Hampton 14·00, Hampton Wick 7·50. The branch sewer to Hook will be as before described, but it will be continued to the low level sewer, and as the whole of the sewage from this part will be pumped, the high level sewer will not be required; the 18 inch pipe sewer will be continued from Rythe Junction as before, and the sewage of Esher will be received at 24·50.

I have carefully considered the subject of disposal and have come to the conclusion that it is better to

dispose of the sewage within the district than to pump it to a distance.

Purity is a question of degree; as applied to water it means fitness, and the object of these works is to obtain an effluent fit to turn into the river at the least possible cost, and the most simple as well as the most scientific way of doing this is to divide the process into two stages; the first stage is now called *Clarification*, and the second *Purification*. The former consists in removing the insoluble elements and matter in suspension, and the latter in decomposing and removing the elements in solution.

CLARIFICATION.

The suspended matter of raw or untreated sewage being slimy and glutinous, and its specific gravity being nearly the same as water, it will only separate very imperfectly after standing a considerable length of time. In order therefore to obtain a clear liquid, it is necessary that some precipitant should be used. A great number of precipitants have been tried and as most of them succeed, we may conclude that precipitation does not require very great nicety in respect of the precipitant, and as regards quantity, we may always say more or less. The most simple precipitant is lime which is ready to hand, and will not injure the water

in the river; its effect in clearing sewage is the same as the white of egg in clearing coffee, or isinglass in fining beer. To this may be added sulphate of alumina.

It is used as follows:—After being slacked and converted into a hydrate of lime, it is placed in a tank, mixed with water by an agitator, worked by steam power, and then added to the sewage, the effect of which is that a clot is rapidly formed which sinks to the bottom and carries with it the insoluble organic impurities, together with the finer particles of suspended inorganic matter.

On entering the works the sewage will be received into a tank properly fitted up for screening the sewage and removing the drift. The drift sinking to the bottom will be deposited in catch pits, the floating matter will be stopped by screen No. 1, floating in the tank. The coarser parts of the suspended matter will be stopped by screen No. 2 and the finer portions by screen No. 3, placed at the end of the tank and covered with basket work. On leaving the screening tank it will be treated with the milk of lime and then passed through a salmon ladder, the projecting boards of which will thoroughly mix it. After flowing along for a considerable distance to give the lime time to act, it will be received into depositing tanks, and the finely suspended matter removed by subsidence.

The depositing tanks are placed at the highest possible level, so that the effluent, after precipitation, can be discharged without pumping, and the tanks emptied and cleansed without the employment of mechanical power: all sewage works should as far as possible, be self-acting, and the whole thing dealt with by gravitation. The tanks at each works are calculated to hold one day's supply for the whole population at the rate of 250 gallons per house. Their united length at each works will be 960 feet and at the combined works double that length. They will be arranged in sets of two. They are adapted to any precipitation process, and any of the tanks can be shut off at pleasure. They are also arranged so as to afford the greatest possible facilities for the subsidence of the sewage, emptying the tanks and removing the sludge. In order not to disturb the falling precipitate, the main sewer at the inlet is depressed, so that the sewage is delivered at the bottom of the tank without any pressure, and a head wall is constructed opposite the mouth of the sewer.

Each tank is emptied once a fortnight, and the process of emptying is as follows:—The sluices being shut down, the liquid is left to subside for 24 hours, it is then gradually run off to the lowest possible level by the usual channel, the aperture in that direction is then closed and a sluice provided

for the purpose is opened at the opposite end of the tank—this outlet is protected by dam boards placed in front, which, being gradually lifted, the sludge is disturbed as little as possible while the tank is being emptied.

When the fluid is run off, the sludge is left to drain and the tanks are arranged so that it runs to the centre: and there is a sump hole at the bottom so that they can be completely emptied. $1\frac{1}{2}$ yards of lime are required for the treatment of $1\frac{1}{4}$ millions of gallons of sewage, and the precipitate is equal to 45 tons of thin sludge, containing 90 per cent of water, which, when air-dried, is reduced to about 7 yards. The precipitation of sewage by lime retards putrefaction for a limited period only, but it is sufficient to enable the precipitated sludge to be disposed of without nuisance. The cost of labour and materials for treating the sewage of 1000 persons by the lime process, in round numbers may be estimated at £15 per annum.

The sludge may be utilized in the manufacture of Stock Bricks as described in Part I of this work.

Clarification makes the effluent in many cases fit to turn into a stream not used for a water supply; reduces the cost of land used for irrigation or filtration purposes, because so large a quantity

is not required, and it removes the coarser particles of organic matter, which otherwise would take a long time to become oxidized, and laying exposed on the surface of the ground would be very offensive.

The result of an analysis of the effluent of Birmingham sewage which had been clarified by lime, shewed that it was still contaminated with organic matter to the extent of about 12 pounds weight per day, per 1000 of population.

PURIFICATION.

Science has pointed out one way, and *only one way* of removing organic matter from sewage, and that is by oxidation.

Oxygen, the most widely diffused body in nature, is the great purifier, decomposing the organic poison of sewage; resolving it into its elements and transforming it into food for plants. It converts that into a blessing which would otherwise become a curse. Exposed to this silent but mighty agent, no organic matter can maintain its permanence; gelatine, fat, fibrine, and sugar, are all gradually arranged into new compounds containing at every step an increased quantity of oxygen.

There is a close resemblance between combustion and oxidation and the terms are almost synonymous, the former being a rapid and the latter a slow

chemical change; the one producing artificial light, the other being luminous in certain cases only, as for example in those of phosphorus, decaying wood, and putrifying fish. The amount of heat generated by the slow process of oxidation, is said to be exactly the same as that evolved during the most rapid combustion of the same substances. Combustion is decomposition by fire; oxidation, decomposition by chemical means: heat being evolved in both cases, and carbonic acid, water, and an oxide being formed.

The oxygen used for sewage purification is obtained from the air, land being employed to separate the sewage into very thin films and to distribute it over an immense area, so that every part of the organic matter may be fully acted upon.

FILTRATION AREA.

Porous land having been obtained in a suitable situation and at a lower level than the depositing tanks, so that there may be no unnecessary expense for pumping—is cut up into plots called filtration areas, which must be properly levelled, provided with cart and barrow roads, and deep drained. The sewage after leaving the depositing tanks, is brought to the highest part of the ground in pipes, and distributed by means of carriers, provided with

suitable sluices and notch plates for regulating the flow. Theoretically, the whole of the land is divided into three portions, which are irrigated in rotation, so that each portion shall receive the sewage for one year, and rest two years. The plots receiving the clarified sewage, are laid out on the ridge and furrow principle, which economizes space and more equally distributes the sewage. Suitable crops are grown on the ridges. The land not under irrigation is cultivated in the ordinary way, and thus the ground is rested and changed. A border of fruit trees instead of a plantation may be placed round the works, and the sewage grounds may be used either as a market garden or a dairy farm.

Land performs the same office in cleansing sewage as the lungs in cleansing the blood, and it is not unlike in its action; both contain innumerable air cells; in the land the air cells are divided by particles of soil, in the lungs by the tissues; in both cases the air is inhaled and exhaled, and the functions are to oxidize the organic impurities; in operation one is called breathing, and the other intermittent filtration.

The land is a self-acting apparatus which will purify as much sewage as it will hold; its capacity, as before observed, depends upon the depth and freeness of the soil. it must be used intermittently, and there must be no stagnation. In practice, as soon as one bed is saturated the sewage

is shut off and passed on to the next. As the liquid enters the soil it expels the air, and as it soaks away, the air again takes its place. It is impossible to construct any apparatus so simple or so perfect in its action as a land filter—self-acting, except as to the supply of sewage—self-cleansing. Besides removing the organic matter by oxidation the land acts beneficially in rendering the clarified sewage again fit to turn into streams, by removing various inorganic impurities, by saturating the liquid with the various soluble elements of the soil, and by making it similar in character to the river water of the district; thus preventing that precipitation in the river which often takes place when a sewage effluent is turned into it.

Sewage water after it has been passed through ærated porous soil as before described, is purified and again fitted for use. It contains very little organic carbon, organic nitrogen or ammonia, but a large quantity of nitrates, which are perfectly innocuous, although they shew by their presence that the water has been contaminated by animal matter.

What is pure water? we must not expect—indeed we do not want to get a pure water. Purity is a question of degree, and as applied to water means fitness. *Absolutely pure water* is flat and disagreeable to drink, owing to the absence of dissolved atmos-

pheric air; fish cannot live in it, and if taken into the stomach of man it is injurious. *Rain water* is contaminated with ammonia or other impurities which it derives from the atmosphere as it falls from the clouds, and as soon as it touches the earth or any other surface it derives further impurities therefrom. *Spring water* contains matter in suspension and in solution, the purest river water being contaminated with inorganic matter derived from the soil over which it has passed. If water be required for chemical purposes, it must be distilled; for drinking purposes, free from organic matter; for manufacturing purposes, free from elements which would be injurious to that manufacture. If a sewage effluent be turned into a tidal river it is sufficiently pure if the matter in suspension and so much of the matter in solution as would occasion a deposit in the river, be removed.

The land first acts as a filter and removes the soluble filth by surface attraction. The organic matter of the sewage then undergoes oxidation. The various substances of which it is composed are broken up and fresh combinations are formed; the oxygen combines with the carbon and forms carbonic acid; with the hydrogen and forms water; with nitrogen and forms ammonia, nitrous acid, and nitric acid, and these last combining with the various bases in the soil form nitrites and nitrates. The hydrogen also combines with the carbon, the phosphorus, and

the sulphur, and forms carburetted, phosphuretted, and sulphuretted hydrogen gases, which occasion the nauseous smells of sewage; and ammonia is oxidized to nitric acid. A process of alternate decomposition, combination, change, and transition from one state of being to another, is continually going on. It is the same with organic life, what plants absorb from the soil and air, they transform into substances on which the herbivorous animals feed, by the latter they are transformed into animal food on which man feeds, and that which is given off in various kinds of decomposition by men, animals and plants, both during life, and after death, returns again into the air and soil, and becomes material for the growth of another generation of plants: the process of transformation recommences, and a perpetual and ceaseless revolution is pursued.

The true theory of purification is only just now understood; the want of this knowledge has caused many mistakes. At one time it was stated or inferred, that the soil acted chemically in purifying sewage. Taking that view of the subject sewage was poured over clay lands for the purpose of purification, but when the operation was completed the sewage was found to be as foul as when it was first put on. At another time it was stated that growing plants had the wonderful power of purifying sewage and rendering the liquid again fit for use, but

this also has been found to be a mistake. Again, theorists value town sewage at 2d. per ton, and to extract this value they require an acre of land for the sewage of every 25 persons of population. Now that the correct theory of purification is understood, it is found that after the sewage has been clarified, an acre of land is sufficient to purify the sewage of from 500 to 1000 persons. The laboratory experiments of Professor Frankland shew that under special circumstances the sewage of 3,737 persons might be applied to an acre of land drained six feet deep; and this is not surprising when we remember that for Waterworks the surface required for filter beds is at the rate of one square yard for every 700 gallons to be filtered in 24 hours, which at 30 gallons per head is equal to 112,933 persons per acre.

The quantity of land required depends upon the depth of free soil, whether it be 3 feet or 20 feet deep, the facilities for drainage, and whether the sewage is clarified or not previous to its application—this process of purification has been arrived at very slowly, but it is one of the most elegant applications of modern chemistry—no cost for chemicals—the means always at hand—nature doing its own work.

I have taken the liberty of discussing the question of sewage purification because there is still a wide difference of opinion, and because I wish to place before you what I consider to be the correct princi-

ples, and to explain my reasons for the arrangement of the present works.

The idea that sewage is of immense value is now almost entirely abandoned, but whilst you must not expect a profit, yet as a waste product which must be disposed of, it can be utilized in growing crops, and it will yield a sufficient revenue to pay a rent if the land can be purchased at a reasonable cost.

The execution of these works will relieve you from all difficulty ; turn to profitable account what would otherwise be wasted; prevent the pollution of the river by sewage, and remove from your midst what is undoubtedly a nuisance to the inhabitants and a fertile source of disease.

In conclusion I submit these schemes with confidence to your favourable consideration.

I am, Gentlemen,

Your most obedient Servant,

EDWARD MONSON.

2, The Vale, Acton.

ESTIMATE FOR SCHEME A.

NORTHERN DIVISION.

SITUATION OF SEWER.	MARKED ON MAP.	GRADIENT.	AVERAGE DEPTH OF SEWER.	INTERNAL DIAMETER OF SEWER	LENGTH IN YARDS.	PRICE PER LINEAL YARD.	COST.
		1 in.	Feet.	ft. in.		£ s. d.	£ s. d.
Mortlake, from Barnes to Richmond	*a*	1056	24	3 0	2596	2 8 0	62 0 8 0
Richmond to Kew Road	*b*	,,	30	3 6	858	3 0 0	2574 0 0
,, to River.....	*c*	,,	42	4 0	1166	3 18 0	4547 8 0
River Thames	*d*	,,	—	6 0	99	—	4000 0 0
Tank Sewer to Works	*e*	,,	40	6 0	1606	9 6 0	14935 16 0
Kew Road to Kew (pipe).....	*f*	660	23	1 3	440	1 1 0	462 0 0
Petersham and Ham (pipe)	*g*	660	10	1 3	3168	0 13 0	2059 4 0
MAIN SEWERS							£34808 16 0
100 Manholes, Ventilators, and Flushing Chambers							2000 0 0
WORKS AT A ON MAP.							
Six acres of Land at £200 per acre							1200 0 0
Engines 50 H.P., for pumping 92,037 gallons per hour, 55 feet lift, including Pumps, Rising Main, Well, Buildings, Roads and Fences.....							6500 0 0
SETTLING TANKS.							
Length, 240 feet. Breadth 240 feet. Depth, 10 feet							6930 0 0
Precipitation Works							1200 0 0
FILTRATION GROUND, P ON MAP.							
111 acres at £200 per acre							22200 0 0
Land Drainage, Carriers, Roads, &c., to ditto, including Outfall Sewer at V							11100 0 0
							£85988 16 0
Contingencies							5268 4 0
Engineering							1726 0 0
							£92983 0 0

SOUTHERN DIVISION.—(Low Level Sewers.)

SITUATION OF SEWER.	MARKED ON MAP.	GRADIENT.	AVERAGE DEPTH OF SEWER.	INTERNAL DIAMETER OF SEWER	LENGTH IN YARDS.	PRICE PER LINEAL YARD.	COST.
		1 in.	Feet.	ft. in.		£ s. d.	£ s. d.
Kingston Works to Junction	*h*	880	24	5 0	1430	3 10 6	5040 15 0
,, ...	*i*	,,	18	4 0	1496	2 14 0	4039 4 0
,, to Long Ditton	*j*	,,	24	3 6	1760	2 11 0	4488 0 0
Long Ditton to Rythe Junction ..	*k*	,,	22	3 0	836	2 7 0	1964 12 0
,, to Esher (pipe)	*l*	,,	18	1 6	3234	0 18 6	2991 9 0
Thames Ditton from Rythe Junc.	*m*	,,	17	2 6	1100	1 15 6	1952 10 0
,, ,, to West Moulsey..	*n*	,,	8	2 0	2508	1 6 0	3260 8 0
							£23736 18 0

ESTIMATE FOR SCHEME A.—*continued.*

SITUATION OF SEWERS.	MARKED ON MAP.	GRADIENT.	AVERAGE DEPTH OF SEWER.	INTERNAL DIAMETER OF SEWER	LENGTH IN YARDS.	PRICE PER LINEAL YARD.	COST.
HAMPTON, &c.		1 in	feet.	ft. in.		£ s. d.	£ s. d
River Thames	*o*	660	—	2 6	44	3 10 0	600 0 0
Hampton Wick to Railway Bridge	*p*	,,	24	2 6	572	2 0 0	1144 0 0
,, to Hampton Green (pipe)	*q*	,,	23	2 0	2794	1 15 0	4889 10 0
							6633 10 0
HIGH LEVEL.							
Lachmere Lane (Embankment) ..	*r*	1056	6	3 0	1188	2 0 0	2376 0 0
Kingston to Norbiton Junction ..	*s*	,,	10	3 0	1518	1 17 6	2816 5 0
From Norbiton Junc. embankment	*t*	,,	3	2 6	550	2 0 0	1100 0 0
to Lower Marsh Lane { iron pipe on brick piers }			—	2 6	594	5 10 0	3267 0 0
Do. to top of Victoria Road.....	*u*	,,	10	2 6	1210	1 12 6	1966 5 0
Surbiton to Hare Lane (pipe)	*v*	,,	7	1 6	5148	0 14 0	3603 12 0
							15159 2 0
NEW MALDEN BRANCH.							
New Malden from Junction (pipe)	*w*	660	18	1 6	1188	0 18 6	1098 18 0
,, to Long Ditton (pipe)	*x*	,,	7	1 6	1782	0 14 0	1247 8 0
Junction to Brighton Road	*y*	220	8	1 3	2332	0 12 0	1399 4 0
Kingston Rural (pipe)	*z*	,,	18	1 0	528	0 11 6	303 12 0
							4049 2 0

SOUTHERN DIVISION SUMMARY.

Low Level Sewers	23736 18 0
Hampton, &c.,	6633 10 0
High Level	15159 2 0
New Malden Branch	4049 2 0
MAIN SEWERS	£49578 12 0
320 Manholes, Ventilators, and Flushing Chambers, at £20 each	6400 0 0
WORKS AT B ON MAP.	
Six acres of land at £200 per acre	1200 0 0
Engines, 29 H.P., for Pumping 87926 gallons per hour, 32 feet lift, including Pumps, Rising Main, Well, Buildings, Roads and Fences	3340 0 0
SETTLING TANKS.—Length, 240 feet. Breadth, 240 feet. Depth, 10 feet	6980 0 0
Precipitation Works	1200 0 0
FILTRATION GROUND AT Q ON MAP.	
111 acres of land at £200 per acre	22200 0 0
Land Drainage, Carriers, Roads, &c., to ditto, including Outfall Sewer at V	11100 0 0
	£101998 12 0
Contingencies	6869 8 0
Engineering	1994 0 0
Southern Division	110862 0 0
Northern Division	92983 0 0
TOTAL COST OF SCHEME A	£203,845 0 0

ESTIMATE FOR SCHEME B.

SITUATION OF SEWER.	MARKED ON MAP.	GRADIENT	AVERAGE DEPTH OF SEWER.	INTERNAL DIAMETER OF SEWER	LENGTH IN YARDS.	PRICE PER LINEAL YARD.	COST.
		1 in	Feet.	ft. in.		£ s. d.	£ s. d.
Mortlake, from Barnes to Kew ..	*a*	1056	24	3 0	2596	2 8 0	6230 8 0
Richmond, from M'lake to Kew Rd	*b*	,,	30	3 6	858	3 0 0	2574 0 0
Do from Kew Road to River	*c*	,,	42	4 0	1166	3 18 0	4547 8 0
Across River	*d*	,,	—	6 0	99	—	4000 0 0
Tank Sewer from River to Works	*e*	,,	40	6 0	1606	9 6 0	14935 16 0
Kew Road Junction to Kew	*f*	660	23	1 3	440	1 1 0	462 0 0
Richmond to Hampton Wick Junc.	*g*	1056	28	5 0	4796	4 0 0	19184 0 0
H'pton Wk. Jn. to Clarence Rd. Jn.	*h*	,,	18	4 6	1408	3 7 6	4752 0 0
Clarence Road Junction	*i*	,,	20	4 0	946	3 0 0	2838 0 0
Kingston to Long Ditton	*j*	,,	20	3 6	1760	2 8 0	4224 0 0
Long Ditton to Rythe Junction ..	*k*	,,	16	3 0	836	2 1 6	1734 14 0
Thames Ditton from Rythe Junc.	*l*	,,	17	2 6	1100	1 15 6	1952 10 0
Thames Ditton to West Moulsey..	*m*	,,	8	2 0	2508	1 6 0	3260 8 0
Long Ditton to Esher (pipe sewer)	*n*	880	18	1 6	3234	0 18 6	2991 9 0
HAMPTON BRANCH.							
Across River	*o*	660	—	2 6	44	—	600 0 0
Kingston and Hampton Wick	*p*	,,	24	2 6	572	2 0 0	1144 0 0
Hampton Wk. from Jn. to Hampton	*q*	,,	23	2 0	3674	1 15 0	6429 10 0
NEW MALDEN BRANCH.							
From Cambridge Rd. to Clarence St.	*r*	44	20	2 0	1298	1 13 0	2141 14 0
New Malden	*s*	660	18	1 6	1188	0 18 6	1098 18 0
,, to Long Ditton (pipe sewer)	*t*	,,	7	1 6	1782	0 14 0	1247 8 0
Hook Junc. to Brighton Rd. (pipe)	*u*	220	8	1 3	2332	0 12 0	1399 4 0
Kingston Rural (pipe sewer)	*v*	,,	18	1 0	528	0 11 6	303 12 0
MAIN SEWERS							£88,050 19 0
Manholes, Ventilators, and Flushing Chambers							8400 0 0
WORKS AT A ON MAP.							
10 acres of Land at £200 per acre							2000 0 0
Engines, 122 H.P., for Pumping 220,309 gallons per hour, 55 feet lift, including Pumps, Rising Main, Well, Buildings, Roads, and Fences.....							8651 0 0
No. 2 SETTLING TANKS.—Length of each, 240 feet. Breadth, 240 feet. Depth 10 feet							13960 0 0
Precipitation Works							1500 0 0
FILTRATION GROUND, P ON MAP.							
221 acres at £200 per acre							44200 0 0
Land Drainage, Carriers, Roads, &c. to ditto, including Outfall Sewer at V ..							22100 0 0
							£188,861 19 0
Contingencies							12256 1 0
Engineering							3923 0 0
TOTAL COST OF SCHEME B.....							£205,041 0 0

ESTIMATE

OF THE

ANNUAL COST OF WORKS.

THE MONEY BEING BORROWED FOR SIXTY YEARS, AND PAID OFF BY EQUAL ANNUAL INSTALMENTS OF PRINCIPAL AND INTEREST, AND THE STOCK BRICK MAKING PROCESS BEING ADOPTED.

SCHEME A.

NORTHERN DIVISION—

Annual Instalment of Loan to repay £92,983 in 60 years				1549	14	4
Interest on £92,983 at 3½ per cent., paid by equal annual instalments				1627	4	0
Annual cost of Pumping and depreciation of Machinery				887	14	0
Annual cost of Clarification—55,545 inhabitants at £15				833	0	0
Flushing				125	0	0
				£5,022	12	4
Cr.						
Rent of 111 acres of Land, with the use of the clarified sewage, at £10	1110	0	0			
Sale or Utilization of 1,600 yards of Manure from screening tanks at 1s	80	0	0			
Profit on utilizing sludge for 2,500 thousand Bricks at 3s	375	0	0			
				1565	0	0
Annual Cost of the Northern Division..						£3457 12 4

SOUTHERN DIVISION—

Annual Instalment of Loan to repay £110,862 in 60 years				1847	15	0
Interest on £110,862 at 3½ per cent. paid by equal annual instalments				1940	1	8
Annual cost of Pumping and depreciation of Machinery				500	10	0
Annual cost of Clarification—55,370 inhabitants at £15				832	0	0
Flushing				125	0	0
				£5,245	6	8
Cr.						
Rent of 111 acres of Land, with the use of the clarified sewage, at £10	1110	0	0			
Sale or Utilization of 1,590 yards of manure from screening tanks, at 1s	79	10	0			
Profit on utilizing sludge for 2,500 thousand bricks at 3s	375	0	0			
				1564	10	0
Annual Cost of the Southern Division..						£3680 16 8
Annual Net Cost of Scheme A						£7138 9 0

SCHEME B.

Annual Instalment of Loan to repay £205,041 in 60 years....				3417	7	0
Interest on £205,041 at 3½ per cent. paid by equal annual instalments				3588	4	0
Annual cost of Pumping and depreciation of Machinery....				2173	12	0
Annual cost of Clarification—110,915 inhabitants at £15				1665	0	0
Flushing				250	0	0
Cr.				£11,094	3	0
Rent of 221 acres of Land, with the use of the clarified sewage, at £10	2210	0	0			
Sale or Utilization of 3,190 yards of manure from screening tanks at 1s....	159	10	0			
Profit on utilizing sludge for 5,000 thousand bricks at 3s.....	750	0	0			
				3119	10	0
Annual Net Cost of Scheme B					7974	13	0

According to our present knowledge, the author believes it to be quite impossible to obtain a pure effluent by precipitation only, but there have been cases in which a low standard of purity has been allowed to pass, and as in this competition Precipitation schemes were sent in, he begs to submit the following additional estimates for the purpose of comparison—not because he approves of that process in this case.

PRECIPITATION SCHEMES.

SCHEME A.

Sewers	£92,787
Precipitation Works	£28,600
Total Cost of Scheme A	£121,387*

SCHEME B.

Sewers	£96,451
Precipitation Works	£26,110
Total cost of Scheme B.....	£122,561*

* These were the cheapest schemes sent in.

THE COMPETITION.

CHAPTER V.

The Board's Instructions to competing Engineers—Description of the various Schemes--The Schemes reported on—The Report inaccurate and unfair—Mr. Haywood's Scheme adopted—The Author's Schemes compared with Mr. Haywood's—The Author has a property in his Schemes.

HE Lower Thames Valley Main Drainage scheme was introduced into this book by the author as a carefully worked out exemplification of his method of treating sewage: it was not at first his intention to refer to that drainage competition, but in the present state of affairs he thinks it better to do so, and it will make his subject more complete.

The Joint Drainage Board was established for the purpose of draining their district; but up to the present time they have utterly failed to carry out the obligations imposed upon them, and in consequence of the delay, the various authorities are dissatisfied, and some, are seeking for a dissolution. The following extract from the *Surrey Comet* of the 10th of March, 1883, will shew the present state of public feeling:—

> "The ratepayers of the Lower Thames Valley are drifting into a very serious position. One of the most ambitious organizations instituted under the auspices of the Local Government Board has proved, so far, after a trial of five years, a miserable failure, and its incompetence to deal with the matter entrusted to it, has not only led to a fearful waste of time and money, but seems likely to bring this

district under a burden which will be almost ruinous to a vast amount of property. It was quite evident from the tenor of the proceedings at the late inquiry that the application of the board for an extension of time, and for protection from the penalties that could be legally demanded by the Thames Conservators, would, if granted, be granted most reluctantly, and in such a way as to exclude all hope of much further extension of grace. They have now, after due consideration, granted the extension of another year In this instance the impatience of the Local Government Board but reflects the impatience of the public, at the wilfulness and apathy which have alternately marked the conduct of the Joint Board, and which have prevented any rational consideration of the opportunities that have from time to time been brought before it."

The cause of the failure has arisen, not from the want of ability, but from the want of technical knowledge on the part of the board: that they were not well up in the subject is shewn from the following extract; it is from the report of the proceedings at the Local Government Inquiry for an extension of time as reported in the *Surrey Comet;* one of the speakers stated that:—

"Thirty odd gentlemen had been brought to the board from all parts of the Lower Thames Valley, most of whom had come totally new to the sewage question; and they had been *educated* upon it, until now they were unanimous upon questions, upon which formerly they were very much divided."

In January, 1878, the Joint Drainage Board decided to obtain a scheme of drainage by a limited competition—only those engineers being allowed to compete, who were selected or approved by the board and the following is a copy of their instructions:—

INSTRUCTIONS TO CIVIL ENGINEERS FOR PRELIMINARY DESIGNS.

1.—The Lower Thames Valley Main Sewerage Board are desirous of receiving from competent Engineers, suggestions as to the best method of disposing of the sewage of the United District, and will be glad to be favoured with your views upon the subject.

2.—The suggestions now asked for are to be considered as preliminary, and are only intended to enable the Board to decide on the principle to be adopted, having regard to the relative cost and efficiency of the various plans which may be submitted.

3.—The accompanying book compiled by Mr. GLEN, Barrister-at-Law, will give all necessary information as to the statutory powers and obligations of the

Board; and the accompanying map (in duplicate) gives the limits of the United District, with the relative positions of neighbouring districts, which have applied to the Local Government Board to be admitted, namely:—Heston and Isleworth, Weybridge, Oatlands Hersham, Worcester Park and part of Cheam, and Kingston Rural Sanitary Districts, the possibility of the inclusion of which should be contemplated. The necessary statistics of the various contributory districts are given in the accompanying table.

4.—It is requested that your plan may be based entirely on the data herewith furnished, even though you may have reason to doubt their correctness in any respect. It will be desirable, however, that you call attention to any supposed errors that you may observe.

5.—You are requested to lay down the principle features of your plan upon the accompanying map of the district, forwarding one copy to the Board and retaining the duplicate for your own use.

6.—You should indicate upon it in plain red lines and figures the proposed lines of sewers, positions of pumping stations, precipitation works or settling tanks, (if any) land for irrigation or filtration, (if forming a portion of your scheme) and other features, and a descriptive paper should accompany the plan. Detailed drawings are not expected, but any that are necessary for illustration of the principles you suggest may be forwarded. You are also requested to give the level at which the Main Sewer will receive the sewage of each contributory District, and the rate of inclination of the sewers.

7.—The quantity of sewage to be dealt with, is by the act directed to be a volume equal to 250 gallons per diem for each house in the United District. The number of such houses to be ascertained from time to time from the Poor Rate in force for the time being. With a view to uniformity in the plans, it is requested that the sewers and other works incapable of enlargement by extension, should be calculated for a discharge of *treble* the present quantity required, while engine power, precipitation works, and other works capable of extension, should be estimated as sufficient for 30 *per cent.* more than the present requirement. Land must be dealt with according to circumstances, such as cost, possibility of extension, &c., but these circumstances should be set forth in detail.

8.—With a view to making a fair comparison of the estimates that may be submitted, you are requested to arrange them as far as possible, according to the accompanying form, adding other heads if the special features of your plan should require them, and giving the estimated cost of each.

9.—An estimate should also be given of the probable annual cost of carrying out the purposes of the Board after completion of the works, naming such as are incidental to your particular scheme.

10.—If your estimate is rendered exceptionally high or low, under any of its heads, by reason of any peculiarity of construction or other circumstances, you are requested to call attention to the items so affected.

11.—Plans should be delivered to the Clerk of the Board, at Kingston, not later than Saturday, the 15th June.

12.—It is to be understood that the Board offers no remuneration for these preliminary suggestions; but they will select the three plans which appear to offer the best prospect of success. The authors of each of these will receive the sum of 200 guineas Should the Board request them or any of them to work out the plans in greater detail, further terms will be agreed upon.

13.—There is a map of the district on the 6-inch scale in the possession of the Board, which can be seen on application to the Clerk.

14.—The Board will be glad to be informed not later than the 13th of April whether you will undertake to furnish them with a preliminary design and suggestions.

The schemes were sent in on the 20th June, the time having been extended.

As the result of the competition, there were 16 competitors who sent in 25 schemes. Of these schemes, four were for the total diversion of the sewage from the district; 12 for irrigation; two for precipitation and irrigation; *two schemes by the author for precipitation—followed by intermittent filtration, on* 200 *acres of land.* There were three schemes for precipitation and filtration—through only 28 acres of land in one case—and 48 acres in two others. There were but two schemes for precipitation only.

The whole of the schemes were handed over to an engineer for analysis, and he states in his report that "his instructions were to refrain from giving any opinion as to the merits or demerits of the respective schemes;" but notwithstanding this he drew particular attention to the fact that 12 out of the 25 were irrigation schemes, by printing the 12 in larger figures than the others!—thus indirectly recommending irrigation. And in paragraph 35 of his report he also drew particular attention to the scheme of Mr. Haywood, by stating that "his economy was due to his having selected a site for irrigation near his pumping station and at a low level, so that his expenses for pumping and subsequent conveyance were small!"—was this refraining from giving an opinion?

Then again as to cost, this report states in table II, in

which the schemes were said to be reduced to a common standard, that Mr. Haywood's scheme would only cost £148,673; whereas Mr. Haywood himself had estimated the cost at £268,000; and, at the inquiry, it was shewn that it would cost, at least, £413,946. So much for the accuracy of this report, now, as to its fairness:—It was stated that in five of the proposed schemes it was intended to collect the sewage at St. Margaret's, which is a valuable residential property, but this was contrary to the fact: only one engineer proposed to do so; the works of all the others being upwards of half-a-mile from that place; and the author complains that his scheme was wrongly described. In this report it it is stated to be a scheme of Precipitation and Irrigation—whereas it is a scheme of Precipitation and Intermittent Filtration.

The Joint Drainage Board acting on this inaccurate, insufficient, and one-sided report; without proper professional assistance; and having no previous experience to guide them; adopted Mr. Haywood's scheme, and having applied to the Local Government Board for permission to put in force the Lands Consolidation Clauses Act; an inquiry, the most elaborate on record, was held, which lasted forty days, and caused an expenditure on the part of the board of £20,000; compelling the owners and ratepayers to expend a further sum of £10,000 to defeat the scheme: thus casting upon the district a useless burthen of £30,000 —one third the cost of main sewers! All this expenditure for want of the information which is contained in this book!

Verily the purification of sewage is a most important subject! although, it is not one of general interest to the public.

The following document was drawn up at the request of counsel to be used at the Inquiry. It is a statement of the advantages, of the author's schemes of Precipitation and Intermittent Filtration; as, compared with the Irrigation scheme of Mr. Haywood; and will be found useful as indicating what defects to avoid in a scheme of drainage.

*** The Estimate for Mr. Haywood's Scheme is obtained from the short-hand notes of the Inquiry, and the references refer to the notes.

LOWER THAMES VALLEY MAIN DRAINAGE INQUIRY.

Edward Monson, Assoc. M. Inst. C.E., I am one of the Engineers that was honored by the Joint Board, with instructions to prepare plans for disposing of the sewage of their district, and I sent in two schemes. Before preparing these schemes I made myself well acquainted with the country, and visited every place within the district that I thought would be suitable for the disposal of the sewage, and the site selected by Mr. Haywood, is in my opinion the worst of them all. It was the first place that I looked at, and although I was pleased with the soil in Walton, I rejected this site:—

I. Because the water was near the surface, and I concluded from the levels, that I should not be able to get efficient drainage.

II. Because I thought that the sewage effluent would be likely to pollute the water supply of the metropolis.

III. Because I did not think the Local Government Board would sanction a Sewage Farm at this spot, after they had refused to sanction a scheme for dealing with the sewage of Kingston at Apps Court.

After a good deal of consideration, I selected for the Southern Division of my Scheme A a place called Fernhill, situate on the Upper Ham Road, to the North of Kingston, marked B on map for the sewage works, and the land for a filtration area I proposed to acquire at or near Ham Fields. The effluent to be discharged into the Tidal Water below Teddington Lock.

MR. MONSON'S SCHEMES A AND B.	MR. HAYWOOD'S SCHEME.
The Site of the proposed sewage works and filtration area for the Northern Division of Scheme A and for Scheme B marked A on plan, is situate within the District of the Joint Sewage Board in the Parish of Isleworth, and the works will be placed upon a knoll in the bend of a stream to the South of Mogden Lane: an isolated spot; in the midst of market gardens, bounded by streams on three sides, and	The Site of the proposed sewage works, filtration area, and part of the land for irrigation, is situate in the Parish of Walton-on-Thames, without the District of the Joint Sewage Board, and the whole of the operations of pumping and manipulating the sewage and sludge will be carried on in the Parish of Walton, which is not in any way interested in the scheme. The scheme is a bad one, and the farm is

Mr. MONSON'S SCHEMES A and B.	Mr. HAYWOOD'S SCHEME.
well removed from valuable residential property.	likely to become a nuisance. The traffic to and from the works will be chiefly through Walton. The inhabitants of Walton will therefore have all the nuisance from this immense area without any benefit, and as the Joint Board have lands within their own District which are much more convenient for collecting and more suitable for the disposal of their sewage, they have no right to acquire this land which is in the Parish of Walton, and without the District of the said Joint Drainage Board.
The Land proposed to be acquired is suitable for intermittent filtration and is not liable to floods.	The Land proposed to be acquired is intersected by two rivers and liable to floods, and in its present state is unsuitable for irrigation or intermittent filtration on account of the subsoil water.
There will be no cuts to make, no rivers to widen, no banks to keep out floods, no weirs to construct, and all the expense of such works will be saved.	In order to prevent the floods and drain the land it is proposed to widen and embank the rivers; to make new cuts and construct weirs and concrete drains.
	The Flood Level in 1879 near to the site of the proposed weir was 34·00 above Ordnance Datum, and in 1877 considerably higher.
	Page 1374, Mr. Bidder, calculates that the water must rise in the cut to 32·25 above Ordnance Datum, in order to carry off the quantity of water that is to come down.
	I have plotted a section from the River Thames along the Ember, cuts 1 and 2, and along the concrete drain to Broad Lane.
	Taking Mr. Bidder's figures, I have marked off upon the section the height of water in the cut 32·25 and allowed a gradient of 3 feet to the mile, and I find from the section that from the bottom of the invert of the drain to the surface of the ground at the termination of the 36 in. drain the depth is 1·20—at the termination of the 33 in. drain 1·60—at the termination of the 27 in. drain 2·40 and at the termination of the 24 in. drain ·70.
	N.B. These depths are taken from the bottom of the drain but the flood water in 1879

Mr. MONSON'S SCHEMES A and B.	Mr. HAYWOOD'S SCHEME.
	would have stood 1ft. 6in. above the outlet and the drains all along must be taken as running half full.
There is a good outfall and the land can be easily drained.	From the recorded level of former floods, from the porous nature of the soil, and from the consequent soakage from the rivers, I conclude that no part of the proposed sewage farm can be properly and efficiently drained in times of flood.
	The soak according to Sir John Coode, being only 1 in 12 it is highly probable that the sewage will sink down between the drains and mix with the subsoil water, and not being exposed to the oxidizing influence of the air, will pass away unpurified and the subsoil water will be polluted to a very great distance. Besides this a considerable quantity of sewage effluent will be retained in the cuts, and the Ember: being unable to get away on account of the floods and the small amount of fall. The farm will in that case act like a huge cesspool or absorbing well, and may become a nuisance and injurious to health. With all these disadvantages whatever may be the quality of the soil, the site is unsuitable for a sewage farm.
Earthenware carriers are provided for the whole of the land.	The whole of the land will have to be laid with earthenware or concrete carriers as the soil is so free, or else the sewage will sink into the ground before it arrives at its destination.
	The sum of £24,442 for preparing, laying out and draining filtration area 9 feet deep, and for preparing and draining the land 9 feet deep, making roads and constructing outfall sewers, is therefore utterly insufficient.
No Bridges or Weirs are required.	It is proposed to construct four bridges over the river and cuts, and construct two weirs, for which the estimate is insufficient.
The Mogden site is out of the way of population and the most convenient spot in the whole of the united district for collecting and disposing of the sewage.	The Molesey site is in the midst of valuable residential property, and situate midway between Claremont and Hampton Court Palace.

Mr. MONSON'S SCHEMES A and B.	Mr. HAYWOOD'S SCHEME.
There is plenty of agricultural land in the neighbourhood suitable for intermittent filtration, so that there is abundant room for extension.	There is no suitable agricultural land for extension, except in the parish of Walton, which is without the District of the Joint Board.
The spot being central is most conveniently situate for distributing the sewage by pumping, over the various lands in the valleys of the Crane and Brent, (which rivers have their outfalls into the Thames below Teddington Lock) should this at any future time be required, and almost the whole of the lands proposed in the various schemes to be acquired for irrigation, can be most conveniently reached by pumping from this spot.	The site is quite at the extremity of the District.
The land is intersected by good roads and well situate for land and water carriage and for getting materials to and from the works at small cost.	This being a roadless area intersected by rivers, new roads and bridges must be constructed at considerable cost, and there is no convenience for getting materials to and from the works.
The works will be approached by a bye lane and nearly concealed from view by trees.	
The sewage will be received into tanks and the coarser part of the solids having been removed, it will be deodorized and clarified with lime. The effluent will then be passed through the soil on the intermittent principle and a pure effluent obtained with the least possible nuisance, by decomposing the organic impurities in solution with oxygen obtained from the air.	The raw sewage with only the coarser parts removed by straining, will be run along ill constructed carriers and poured upon the ground, leaving the organic matter on or near the surface, and it will be washed into the drains, cuts and rivers, and finally swept into the river opposite Hampton Court Palace, and above the intake of the drinking water for the supply of the people of London.
[The precipitated sludge being deodorized will be utilized as malm in the manufacture of stock and other building bricks, which will effect a considerable saving in the cost of treatment, and remove all difficulty as to the disposal of the sludge.]	The sludge without being deodorized will be dug into the ground.
The irrigation ground being near to London, there will be a market for the produce of the land close by, which will greatly enhance its value.	The irrigation grounds being far removed from London, there will be no convenient market for disposing of the produce.
[There will also be a market for the bricks.]	
The tanks being placed on high ground	The sewage will be distributed by

Mr. MONSON'S SCHEMES A and B.	Mr. HAYWOOD'S SCHEME.
the sewage can be distributed upon the adjacent lands by gravitation.	pumping, and as there will be no tanks it must be distributed day and night, Sunday and week-days.
There is no other place in the District that possesses so many advantages.	
The land selected at Mogden Lane is a very eligible site for precipitation works, and the effluent can be discharged into a stream which already receives the effluent water from the Twickenham Sewage Works, and falls into the Thames at the rear of Isleworth Ait—below Teddington Lock.	
This stream has no connection with the Crane, and the water which supplies the mill will not be interfered with.	The Water which supplies the mill will be interfered with.
The estimated cost of either scheme A or scheme B is less than that of any other competitor, and they can be carried out either as Precipitation or Irrigation Schemes. The gradients also are better than those in any other scheme, and the sewage flowing to the works without any intermediate pumping stations there is less risk of accident, and less danger of nuisance.	
The site for the proposed works in Mogden Lane, and the outfall for the effluent, are unequalled in the district.	If it were necessary to take the land at Molesey because no other site could be obtained, the proposed works would be very objectionable, but there would be some excuse for it: no such necessity exists.
The proposed method of dealing with the sewage by Clarification and Intermittent Filtration, is the most scientific, most perfect, and most certain method of obtaining a pure effluent, [and the sludge will be converted into a marketable article and completely disposed of without a nuisance.]	
The Estimate has stood the test of official scrutiny without being materially altered, and the prices appear to have been taken as a standard to which all others have been reduced. And when it first came before the Joint Sewage Board W. Parkes, Esq., M.Inst.C.E., is reported in the *Surrey Comet* to have said of these schemes, "That he had well considered Mr. Monson's Report and he felt bound to say that it was drawn up with great care and considerable ability, and the Estimate was made out very clearly."	The Estimate on cross-examination has increased from £148,673 to £413,946, and that is insufficient.

Mr. MONSON'S Scheme A.	SCHEME B.	Mr. HAYWOOD'S Scheme.
The District of the Joint Drainage Board being divided into two parts, it is proposed to call one the Northern, and the other the Southern Division, and construct separate works for each.	The District is dealt with collectively. There will be only one Sewage Works.	The District is dealt with collectively. There will be only one Sewage Works.
There will be two Pumping Stations, but in no case will the sewage be lifted more than once.	There will be only one Pumping Station, and the sewage will be lifted only once.	There will be three Pumping Stations, and the sewage from Barnes, Mortlake, Kew, and part of Richmond, will be lifted three times, and the whole of the sewage from the Northern District and from Teddington and part of Hampton Wick, will be lifted twice.
The outfall for the effluent from each division will be discharged into the tidal waters below Teddington Lock.	The outfall for the effluent is into the tidal water below Teddington Lock.	The effluent will pass into the Ember, and be discharged into the Thames opposite the grounds of Hampton Court Palace, and above the intake of the Water Companies.
High and Low Level Sewers are provided for each division so that:—	High and Low Level Sewers are provided so that:—	There is only one set of main sewers, and the whole of the sewage will be pumped as well as the rainfall from roofs and yards which must be admitted into the sewers.
7,000 acres in Surrey will be drained by gravitation 5,000 acres in Middlesex do.	5,000 acres in Middlesex will be drained by gravitation.	
12,000 acres drained by gravitation. 16,000 acres drained by pumping.	23,000 Drained by pumping.	No part of the district will be drained by gravitation.
28,000 acres Total Area of District.	28,000 acres Total.	
The sewage from nearly half the district being collected and disposed of by gravitation, will effect a large saving in the annual cost of pumping, especially for the prospective population; obviate the necessity of providing large	The saving in pumping will be less than in scheme A.	The present sewers are not sufficient for the prospective population and rainfall that must be admitted, they will therefore have to be constructed larger at the present time, which will increase the estimate, or

Mr. MONSON'S Scheme A.	SCHEME B.	Mr. HAYWOOD'S Scheme.
sewers for storage; diminish the risk of flooding; and afford facilities for extending the system as the population increases, without having to relay the low level sewers; the works may be regarded as permanent works; the cost of which may fairly be spread over a period of 60 years.		they must be re-constructed at a future time. This scheme therefore in its present form is not a permanent work, and ought not to be spread over a period of 60 years.
This arrangement will also save the cost of pumping a large portion of rainfall which must be admitted into the sewers; afford facilities for dealing with the sewage as at present collected; and may obviate the necessity of whole districts having to reconstruct their present system of sewers.	The same remark applies to this scheme as to Scheme A to a limited extent.	The proposed scheme is altogether unsuitable for the wants of the district, because it does not deal with the sewage from the various districts as at present collected, and it cannot be modified hereafter without incurring considerable expense, should it be thought necessary to do so. In its present form it requires a sewage pond to be constructed in every District, or machinery to regulate the flow of the sewage, and also a separate storm overflow to prevent flooding.
SOUTHERN DIVISION.		
The Low Level Main Sewer in the Southern Division is laid so as to follow the natural fall of the ground, which gives an advantage in fall of about one foot to the mile, and keeping the sewer nearer to the surface of the ground reduces the first cost of construction, and affords facilities for inspecting, cleansing and connecting.	The Low Level Sewer is precisely the same as in Scheme A as far as Kingston except the gradient.	The Main Sewers are laid up stream contrary to the fall of the ground, and they are very deep, which make them costly to construct, and very inconvenient to get at.
The gradient for the Low Level Sewer of the Southern Division from West Molesey to Kingston is 1 in 880 = 6 feet to the mile, which is a better gradient than that obtained in any other scheme.	The gradient for the Low Level Sewer from Molesey to Isleworth, and from Barnes to Isleworth, is 1 in 1056 = 5 feet to the mile.	The gradients of the Main Sewer from Richmond to the Works at Molesey are as follows:— Richmond to Ham 1 in 1760 Ham to Pumping Station ,, 1320

Mr. MONSON'S Scheme A.	SCHEME B.	Mr. HAYWOOD'S Scheme.
The Main High Level Sewer has a gradient of 1 in 1056 = 5 feet to the mile from Esher to Kingston. Only the Low Level Sewage will be pumped and the lift is 32 feet.	The High Level Sewer from Esher to Kingston, is omitted in this scheme.	Pumping Station to Kingston 1 in 1500 Kingston to Malden Branch ,, 2000 Kingston to Surbiton ,, 2000 Surbiton to Pumping Station ,, 1900
NORTHERN DIVISION. The gradient of the Main Sewer in the Northern Division from Barnes to Isleworth is 1 in 1056=5 feet to the mile. The Low Level Sewage only will be pumped and the lift is 55 feet. There will be no intermediate pumping. The drainage of every part of the District is provided for, and the sewers of each contributory district will be intercepted at their present level, and in no case will the sewage of the District sewers be backed up. All the sewers will be self-cleansing, and the Tank Sewers are sufficiently large for men to work in.	The Low Level Sewage will be pumped at Isleworth and also the High Level Sewage from the Southern Division of Scheme A and the lift is 55 feet. The sewage from every part of the District will flow to the works by gravitation, and there will be no intermediate pumping.	This Scheme is remarkable for having three pumping stations, and the effect of this arrangement will be, that the sewage at the Richmond Pumping Station when the pumps are not at work will head back in the sewers to Mortlake and Kew, and being stagnant there will be a deposit which will become putrid; be a nuisance to the neighbourhood and injurious to health. This putrid sewage, after being pumped at Richmond will flow sluggishly along a sewer having a fall of only three feet to the mile to Ham; and from thence to the Pumping Station at Kingston; the gradient there being 1 in 1320. When the pumps are not at work at Kingston the sewage will head back towards Richmond; there will be a further deposit in the sewers; and the sewage having become still more putrid, will afterwards be pumped into the Kingston Sewer and continue its pestiferous course along a sewer laid beneath the streets of

Mr. MONSON'S Scheme A.	SCHEME B.	Mr. HAYWOOD'S Scheme.
		Kingston and Surbiton, with a gradient of only 1 in 2000 or 2 feet 7½ inches per mile. When the pumps are not at work at Molesey, the sewage will be headed up at Long Ditton towards Surbiton, and there will be a still further deposit. The so called sewers being elongated cesspools, and there will be a nuisance almost from end to end of the District.
The capacity of the main sewers at the outlet ends has been purposely increased for the purpose of providing storage room for the sewage when the pumps are not at work, and because they partake of the character of works incapable of enlargement, they are increased in order to obviate the necessity of their being reconstructed as the population increases.	The same remark applies as to Scheme A.	No provision is made in this scheme for storing the sewage when the pumps are not at work, the district will therefore be liable to flood, or the raw sewage will be discharged into the river by the storm overflows, and when the sewers are running nearly full the sewage gas will be forced up the various drains into the houses of the inhabitants. Besides this there are no tanks to receive the sewage, and it must be pumped directly on to the land.
The discharging capacity in cubic feet per minute of the Main Intercepting Sewers as per Mr. Buchanan's Table No. 6.		
Edward Monson's Scheme A 9945 cubic feet.	Edward Monson's Scheme B 5311 cubic feet.	W. Haywood's Scheme, 2800 cubic feet.

Mr. MONSON'S Scheme A.	SCHEME B.	Mr. HAYWOOD'S Scheme.
There are no syphons to cross the River.	No syphons.	The River Thames is crossed by syphons from Isleworth to Richmond, and from Hampton to Molesey. In fine weather these syphons will not run full and will silt up so that the water way will probably be reduced to the size sufficient to take only the ordinary dry weather flow of sewage, therefore the districts of Isleworth and Hampton will be liable to flood, or the raw sewage will pass into the river by the storm overflows. Again the floating matter will not descend and pass through the syphons, but will remain floating on the surface on the Middlesex side of the river, giving off its noxious odours amongst the villas of St. Margarets and at Hampton; each syphon will in fact become a cesspool 300 feet long, containing decomposing and putrid matter, and there will be no means of emptying the syphons except by pumping or stirring up the sewage.

THE COST OF Mr. MONSON'S SCHEMES COMPARED WITH THAT OF Mr. HAYWOOD'S.

Mr. MONSON'S SCHEMES.	A. £	B. £	Mr. HAYWOOD'S SCHEME.	£
Main Sewers, Ventilators, &c.	92,787	96,451	Main Sewers, Ventilators, &c.	130,646
Sewage Works and Site..	28,600	26,111	Sewage Works, and Sites:— Pumping stations..... 29,810 Pumping station, Bridges, and site of Pumping Works..... 6,000	35,810
			Straining Tanks	2,000
Total Cost of Collection and Precipitation Works, exclusive of Incidentals and Engineering	121,357	122,561	Total Cost of Collection and Works, exclusive of Tanks, Incidentals, and Engineering	168,456
222 Acres of Land at £200	44,400		916 Acres of Land.....£160,000	
221 „ „ at £200		44,200	Legal Expenses and Compensation 40,000	200,000
222 ACRES LAND:			916 ACRES LAND:	
Drainage, Carriers, Roads, Preparing Land, Outfall Sewers } at £100	22,200		Drainage, carriers and roads 11,729 Preparing Land and constructing outfall sewers 12,713	24,442
221 Do..... at £100		22,100		
			Improving river and constructing new channels and weirs 4,2 5 Puddle Wall.. 5,813	10,048
Contingencies	12,138	12,256	Contingencies.....	*nil*
Engineering	3,720	3,923	Engineering	11,000
Total Cost of Mr. Monson's schemes for Precipitation and Intermittent Filtration	203,845	205,041	Total Cost of Mr. Haywood's scheme, as given to the Inspector by Mr. Latham, question No. 17,639	413,946

ANNUAL COST.

The money being borrowed for 60 years, and paid off by equal annual instalments of principal and interest, as per Report	£8,018	£8,884	The money being borrowed for works for 30 years at 5⅝ per cent.; for land for 50 years at 4½ per cent.	£21,925

As the result of the inquiry by the Local Government Board, Mr. Haywood's scheme was not approved, and now at the end of five years; after much labour; much expense; and the loss of much popularity on the part of the Board; they have found that not only was the site which had been selected by Mr. Haywood unsuited for the disposal of their sewage; but, that sewage irrigation is unprofitable, and not at all suited to the wants of their district. Another method which has been put prominently before them is that of total diversion; and that they have found to be impracticable or inexpedient.

Having rejected Irrigation and Total Diversion; the Board have now, *only one way* of dealing with their sewage effectually, and that is by Precipitation, followed by Intermittent Filtration at works constructed at one or two places within their district, with such modifications as may be necessary to meet the altered circumstances of the case. *That is the Author's scheme;* and in this competition he claims it as his sole property, as no other engineer proposed to adopt this process. It is the outcome of the many years thought and study which he has given to the sewage question; it cost him a good deal of money out of pocket; and a great deal of labour to produce: for he made himself thoroughly acquainted with the district, before he designed his scheme. As the result of the Inquiry; and from the discussions which have taken place; he now boldly asserts, that his scheme is not only the *best* practicable scheme sent in; but also the *cheapest;* as is shewn by

the estimates commencing at page 112 of this book; and it deals with the combined district as a whole: connected together for sewage purposes. With his stock brick making process added, which is new: it is the most perfect and scientific method of treating sewage, that has been yet discovered. A scheme of precipitation and filtration through a small quantity of land, may, to the uninitiated, appear to be the same process, but it is not so: the two processes are totally different: intermittent filtration is a perfect process, in which the organic matter in solution is decomposed, there is a true chemical change, and the purification is complete; whilst on the other hand, filtration through a small quantity of land, is a makeshift process, which only acts mechanically, and although it improves the clarification of the sewage, does not remove the organic matter in solution: the former process is infinitely superior to the latter.

In a limited competition like this,—where those only were allowed to compete who were selected or approved, all the Engineers are, or ought to be, on equal terms. So far as the board are concerned they have no right to give one the preference over or before another; that is the very essence of such a competition. But from the outset there appears to have been on the part of some of the members, a greater desire to employ certain individuals, than to obtain the best scheme of drainage for their district.

It will be seen by the terms of the competition, sec. xii. of the "Instructions to Engineers,"* that the board were to

*See page 119, ante.

select three plans, *which appeared to offer the best prospect of success;* and the authors of each of these were to receive 200 guineas; but the board, as we have seen, selected three plans *which offer no prospect of success whatever;* and backed by the before-mentioned, imperfect and one-sided report, proceeded to award the premiums. To whom? To those happy individuals who were so fortunate as to possess sufficient weight and influence at the Board. For what? For schemes, which they now find to be impracticable, or unsuitable for their district; inadvertently—putting it mildly—doing a great injustice to those engineers, whose schemes they now find, offer a far better prospect of success than those which were premiated.

But that is not all; not only have the premiums been improperly awarded, but there now appears to be a disposition on the part of the Board, to avail themselves of one of the schemes which were not premiated without employing the author of such scheme to carry it out; which is most unfair; totally at variance with the terms of the competition; and contrary to all principles of equity and justice.

In conclusion, the author, hopes that his book, will help on the great work of sewage collection and sewage purification, which is so difficult, and yet so important to sanitary authorities. Instead of dealing with mere theories, he has thought it better to give practical illustrations, and he believes this to be the first work which has dealt so exhaustively with these subjects.